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S.CURTIS.

AGRICULTURAL CHEMISTRY;

OR,

CHEMISTRY APPLIED

TO EXPLAIN THE PRACTICE, AND TO PROMOTE,

UPON RATIONAL PRINCIPLES,

THE IMPROVEMENT OF AGRICULTURE.

"There is no profession which can be compared in importance with that of Agriculture: for to it belongs the production of food for man, and for animals; on it depends the welfare and development of the whole human species, the riches of states, and all commerce. There is no profession in which the application of correct principles is productive of more beneficial effects, or is of greater and more decided influence."—BARON LIEBIG.

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PREFACE.

In those arts which contribute to the welfare, comfort, and happiness of mankind, it has ever been found that their progress towards perfection has been slow or rapid, in proportion to the degree of knowledge of the principles upon which they are founded possessed by those who practise them. Of this we have the most striking proof in the low condition of our manufactures during many centuries, compared with their rapid advancement and the high degree of perfection they have attained in the course of a few years, since the cultivation and general diffusion of the sciences of Chemistry and Mechanics. The enormous power of late years employed in the operations of mining, by which the treasures of the earth are drawn from previously unreachable depths, and

shaped into ten thousand forms of usefulness and convenience; its application in multiplying the production of the loom, in which its operations are made to exceed the skill of the finest touch; the employment of the same power in facilitating internal traffic, and speeding the intercourse between distant nations; the perfection that chemistry has lately imparted to the arts of dyeing and bleaching; the improvement it has effected in the practice of medicine, by which life is preserved and suffering mitigated; and lastly, the combined effort of chemistry and mechanics in giving the lightning's speed to the communication of thought in the invention of the electric telegraph, are amongst the most striking and familiar instances of the benefits mankind have derived from the cultivation of these sciences and the application of the principles drawn from them to the arts and uses of life.

But while almost every other art has more or less felt the beneficial influence of the progress of science, agriculture, the first and most important of all, has been almost the last to claim its share of this means of improvement; for until the last half century, it had derived little or no benefit from mechanical science, and it is only within a very few years past that chemical knowledge has been effectually brought to its assistance. Till

lately, indeed, the cultivation or any degree of knowledge of either of these sciences has not been thought at all necessary or beneficial in the education of a farmer, although they are both intimately connected with all his operations. The gradual diffusion of general knowledge amongst agriculturists, as well as other classes; the necessity of rendering the soil more productive for the sustenance of an increasing population, and a more searching inquiry after all the means of effecting that object, have led to the conviction, amongst the most enlightened farmers, that some degree of chemical knowledge is essential to the perfection of agriculture. It is the object of this little work on Agricultural Chemistry to impart such a degree of information on the subject as will enable the practical farmer to found his plans of improvement and direct his operations upon rational principles, drawn from a more intimate and perfect knowledge of *the nature and properties of the agents he employs*, upon the right use of which, the improvement of the soil and the full development of the power and resources of cultivation, and consequently his own success, so entirely depend. A knowledge of the means which nature employs in the production of the numerous useful and beautiful forms of vegetable life which we see around us, the

support of all animal existence, may well attract and deserve the attention of every mind capable of reflection and the pleasure of mental exercise; and the acquisition of such knowledge will amply reward the application of the rational inquirer; for at every step of his progress he will discover new cause for admiration of that infinite Power and Wisdom, whose laws control alike the enormous masses of the rolling worlds, and the motions and combinations of the *invisible atoms* of which they are composed, rendering them subservient to His beneficent purposes, by the continual renewal of innumerable forms of vegetable and animal existence, which minister to the support and happiness of the rational part of His creation.

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AGRICULTURAL CHEMISTRY.

CHAPTER I.

ELEMENTS, AND THEIR CHEMICAL PROPERTIES.

ALL the various forms of matter by which we are surrounded, and which come within the reach of our investigation, consist of a comparatively small number of *elements*, or primitive forms of matter, having properties distinct from one another: the total number at present known not exceeding fifty-six. Many of these, however, are of rare occurrence and of unimportant amount; and the great bulk of the surface of the globe which we inhabit, and all the innumerable forms of life which it supports, comprise no more than fourteen or fifteen at the most, the remainder consisting principally of metals and other substances not at all connected with the subject of agriculture. The knowledge of these elements, and the laws by which they are governed, constitutes the science of chemistry; and it is needful to take a general view of such laws before we proceed to the consideration of the character of the very few with which we are more particularly concerned.

Besides the attraction of gravitation, which affects all matter alike, and acts at the greatest

distances, and the attraction of adhesion, which exerts itself only in close contact, and unites different bodies together in a firm mass, the elements are subject to a law which is called *Chemical attraction*, by which they unite and form substances differing in character and properties from the elements of which they are composed, and are therefore called *neutral compounds*. This tendency of one element to unite with another is called *chemical affinity*, and the union itself is *chemical combination*. Each individual element, however, manifests this tendency to unite with others in very different degrees, and this partiality or preference of one for another is called *elective affinity*.

In these chemical unions of the elements to form neutral compounds, they combine in certain exact and known proportions by weight, and in no other; for instance, if 1lb. of the gaseous element called hydrogen be mixed with 8lbs. of another gaseous element called oxygen, and fire be applied to the mixture, these gases instantly unite and form 9lbs. of the neutral compound water; but if there had been more than 1lb. of hydrogen, or, on the other hand, more than 8lbs. of oxygen, the excess in either case would have remained unchanged, and only the same quantity of water would have been produced. The number expressing the weight of the combining quantity of each element is called its *equivalent*, or combining proportion: thus the *equivalent* of hydrogen is 1, and that of oxygen 8. Water, the neutral compound formed by the union of these elements, has also its equivalent number, which is the sum of its two elements, 9. In numerous instances, one, two, or

more equivalents of one element, will unite with one, two, or more equivalents of another element, producing compounds of very different properties from each other. Thus the equivalent number of carbon (charcoal) is 6, and if 6lbs. of that substance be burnt in 8lbs. or 1 equivalent of oxygen gas, the result will be 14lbs. of *carbonic oxide;* but if 16lbs, or 2 equivalents of oxygen be used, the resulting compound will be 22lbs. of *carbonic acid gas.* It must be evident from what has been said before, that the equivalent number of carbonic oxide must be 14, and that of carbonic acid 22; and in these proportions they unite with other substances. It matters not whether we use pounds or grains in the illustration of the doctrine of equivalents, as they are mere terms of *proportion,* and not of any absolute quantity. If 28 grains, one equivalent of lime, which is a compound, as will be hereafter shown, be dissolved in water, and the solution be agitated in a jar with 22 grains or one equivalent of carbonic acid, they will unite in a solid state, the lime will lose its burning property, and fall to the bottom of the jar as an insoluble compound called *carbonate of lime,* thus showing that compounds unite in the proportion of their equivalent numbers in the same manner as elements.

We have spoken of the *elective* attraction, or affinity of elements, by which each has a tendency to unite with some other element in preference to the rest. The same law exists in their compounds. If the carbonate of lime, above mentioned, be separated from the water, and a strong acid, vitriolic acid for instance, be poured upon it, the lime will elect the sulphuric acid, by reason of its

stronger affinity for it than for the carbonic acid, which latter will escape in the form of gas, causing a strong effervescence. Very numerous instances of this so-called elective affinity occur in the chemistry of nature. The various elements which compose vegetable and animal substances, have their affinities controlled by that mysterious power called the vital principle, which causes them to combine under different arrangements than they would otherwise assume. When, however, this power ceases, that is, when the plant or animal dies, the elements assert their proper actions, each unites with that for which it has the strongest affinity, new combinations are formed, and an entire disruption of the organic structure ensues. *Decay and putrefaction* are such instances, in which the elements resolve themselves, by their *elective* affinities, into more simple and permanent compounds, and thus become fitted to supply the materials of new forms of existence.

Such as we have briefly described are the laws impressed by transcendent wisdom and power upon the elements or atoms of all matter, by which they are made to assume that infinite variety of form and life, of beauty and grandeur, which the works of creation everywhere exhibit to our view.

It has been before noticed, that though there are about fifty-six elements, a small number only of them constitute the great bulk of natural objects. The latter are all comprehended in that portion which forms soils, or affords the materials of vegetable and animal existence. These important elements are the following:—Hydrogen, oxygen, carbon, nitrogen, chlorine, sulphur, phosphorus,

iron, manganese, alumina (or the pure matter of clay), silica (flint), potash, soda, lime, and magnesia. The six last of these are not, strictly speaking, elements, as they consist of certain metallic elements united with oxygen; but as these metals are never found uncombined, it will be most convenient to consider them in the light of elements. As, however, they unite with other elements besides oxygen, they will be noticed under the head of each of the above compound forms. The first four of the above elements are, in the language of chemists, called *organic elements*, because they form the organs of plants and animals; all the rest are called *mineral elements*, because they are found in the earth, but they are equally essential as the former to the existence both of plants and animals.

In order to have any clear views of agricultural chemistry, it will be needful to understand the nature and properties of these substances: as, in their various combinations, they constitute the materials upon which the agriculturist operates, as well as of those which are the objects of his labours and hopes.

In imparting any degree of knowledge of a science which is new to the reader, it is indispensable to use the terms by which alone it can be taught; but as agricultural chemistry is only a limited branch of that beautiful science, the learner will not be very severely taxed in acquiring the names of the elementary materials and their compounds, and so much of their several properties as are indispensable to his object. This is rendered so much the more easy, because the names of chemical compounds are expressive of the nature of their composition, as will be seen as we proceed.

OXYGEN.

This element, in the form of gas, constitutes about one-fifth of the atmosphere, and its presence is every moment indispensable to the existence of animals, on which account it was once called vital air. It is no less essential to the life of plants. It combines with all the other elements, except the substance or element called fluorine, either in a gaseous, fluid, or solid form; with carbon it forms, as we have seen, carbonic acid gas, with hydrogen, the fluid water, and with metals it forms those substances called metallic oxides, (of which the rust of iron, and red lead, are familiar instances,) and in this shape it forms about half the solid substances of the crust of the earth. Its equivalent number, as before stated, is 8. Oxygen is an acidifying principle, and enters into the composition of most acids. When we inhale common air, the oxygen it contains is converted, by its union with the carbon of the blood in the lungs, into carbonic acid, and with the hydrogen into water, and in these states is again given out in the act of breathing, blended with azote, the other constituent of the atmosphere. The air thus expelled from the lungs is no longer capable of sustaining life, owing to the absence of pure oxygen, or rather its conversion into carbonic acid gas and water, in the manner above noticed; and the distress felt in crowded assemblies of people in closed apartments, sometimes almost approaching to suffocation, is owing to the same cause. In such cases the life-giving gas becomes deficient, and distress, feebleness, and languor are the consequences of the privation. A due supply of oxygen

is no less essential to the existence and health of plants than of animals. It is absorbed by all soils, but more abundantly by those which are rich in animal and vegetable matter, and which require its presence to prepare them for the food of plants. The presence of free oxygen in the soil is also indispensable to the germination or sprouting of seeds, which never takes place when air is excluded—a fact which must be familiar to every farmer in the perishing of seeds in clay land, when in wet weather they are trodden down by the feet of heavy cattle and thus excluded from the air. The watchful farmer, fully aware of this, ceases to sow in such land, when the harrows will no longer erase the footmarks of the horses that draw them. The access of oxygen to the roots of all plants is likewise needful to their growth, and especially to those of corn plants, to promote their tillering, or forming new shoots or offsets, and this is effected by loosening the earth by the hoe; for by this operation, a plant of wheat in good ground, which has been much thinned by a severe winter or by insects, is often made to produce an abundant crop.

Oxygen is the active agent in effecting the decay and decomposition of dead animal and vegetable substances, and their destruction by fire, as such substances will neither decay nor burn when entirely excluded from the air, as in a vacuum, or by being buried deep in the ground, or under water. As soon as life ceases in vegetables or animals, at ordinary temperatures the action of oxygen begins to effect their dissolution, and never ceases until they are completely disorganized, and their elements resolved into new compounds. Burning is a more rapid decompo-

sition of such substances, by the same powerful agent at a higher temperature; and in this case all except the ashes are united with oxygen, the bulk being resolved into gases, chiefly carbonic acid, and the vapour of water. We have familiar instances of this energetic action of oxygen in the burning of candles and the consumption of coals in the fire, called combustion. The elements of which these substances are composed are not destroyed, but only converted into new compounds, as above stated.

It must be obvious, that by the breathing of animals, and the destruction of animal and vegetable substances, both by decay and burning, a great consumption of oxygen must be constantly going on, and it might naturally be inferred, a diminution of its quantity in the atmosphere to an injurious extent. This, however, is prevented by a beautiful economy, which presents one of the most admirable instances of the profound and beneficent wisdom of the Author of nature. That oxygen which is removed from the atmosphere by the means above mentioned, is again restored to it by the process of vegetation. The leaves of plants are the laboratories or workshops in which are prepared the juices which increase their bulk and produce their fruit; and these curious organs, by means of their innumerable pores, abstract the carbonic acid from the atmosphere, the carbon of which they separate from the oxygen, and set the latter at liberty. By this restoring process, the balance is so evenly kept, that no sensible diminution of oxygen in the atmosphere can ever be discovered.

HYDROGEN.

Hydrogen, or inflammable air, as it is sometimes called, is the lightest of all gases; the equivalent number of its atom is 1; combined with one equivalent of oxygen, 8, as before stated, it forms water, and in that proportion with oxygen, forms nearly half the dry inflammable substance of the plants, called woody fibre, as well as of the starch and sugar which many vegetables contain. It enters also in a solid form into the composition of vegetable and animal oils and fats, which owe their great inflammability to the excess of hydrogen they contain above what is necessary to constitute woody fibre, starch, or sugar. Let it here be understood, that the hydrogen and oxygen of dried plants, and of sugar and starch, are not combined as water, but only exist in these substances in the *proportion* necessary to form it.

When oil or coal is distilled in close vessels, as in the gas retorts, the hydrogen of these substances unites with a part of the carbon, and produces the gas called carburetted hydrogen, with which our streets are lighted, and is the same as the inflammable gas of coal pits. This gas is formed by heat in the burning of a candle or lamp, which, as it rises from the mass, undergoes combustion. The lively light of a wood or coal fire is produced in the same way; for when all the inflammable gas has been consumed, we have only the dull light produced by the burning of the carbon or charcoal which the hydrogen has not carried off. All animal and most vegetable substances contain some portion of sulphur and phosphorus, and during their putrefaction and

decay, hydrogen unites with these substances, and forms with them those offensive and poisonous gases which issue from our drains and sewers, and are so injurious to health wherever the causes exist that produce them.

From the extreme lightness of hydrogen gas, being fifteen times lighter than common air, it was formerly used to fill balloons, for which purpose the lightest kind of coal gas is now substituted, as being much cheaper.

CARBON.

This is the most abundant element in all organic forms, whether vegetable or animal, as it constitutes about 45 per cent. of dry vegetable matter, and about 55 per cent. of dry flesh. It also forms the principal part of mineral coal. It is very combustible, and when heated to a certain degree in the open air, readily takes fire. Its equivalent or combining proportion is 6. One equivalent of this element unites with one equivalent of oxygen, 8, to form carbonic oxide, and with 2 equivalents, 16, to form carbonic acid, as before stated. If 6lbs. of charcoal be burnt in a close vessel with 16lbs. of oxygen gas, the *same volume* of carbonic acid gas will be produced, weighing 22lbs. This gas constitutes the choke damp of coal mines and sometimes of wells, and is the cause of death in closed apartments when charcoal is burned. Carbonic acid gas is constantly found in the atmosphere, of which it constitutes about 1000th part by weight, and it is from this source that plants derive directly or indirectly all their carbon; the leaves taking it directly from the air, and the roots from decaying vegetable matter in the soil, which had

before obtained it from the same magazine. It is in the state of carbonic oxide and carbonic acid gases, that vast quantities of carbon are lost to the farmer by needless fermentation of his farm-yard manure.

Carbon in the state of charcoal is a powerful antiseptic or preservative from putrefaction; for if meat be kept in powdered charcoal or in water containing that powder, it will be preserved for some time from putrefaction, and even by washing meat considerably tainted with such water it will be restored. It is a great promoter of vegetation, as plants placed in powdered charcoal, and kept well watered, grow very rapidly, and the smallest cuttings, or sometimes even leaves, strike root readily in pots containing it. Carbon exists in great abundance in sea water, in the state of carbonic acid, from which source the vast forests of sea-weed obtain their carbon. Pure limestone (carbonate of lime), contains about 12 per cent. of carbon, united with the lime in the state of carbonic acid. After what has been stated of this element, it is scarcely necessary to observe that carbon is one of the most important of fertilizing substances.

NITROGEN.

This element is indispensable to the existence of all plants as well as of animals, though it is contained in much greater quantity in the latter than in the former, and this proportion constitutes the principal difference between animal and vegetable substances. Its combining proportion or equivalent is 14. It is owing to the weak affinity of this element for others, that animal substances are so very

prone to undergo dissolution by putrefaction. During this natural process, the nitrogen of the substance unites in the proportion of 1 atom, or equivalent, with 3 atoms, or equivalents, of hydrogen to form ammonia. It may here be as well to observe, that in speaking of combining proportions, the terms atom and equivalent are indifferently used, as they have the same signification.

Nitrogen is also the foundation or radical of nitric acid, as that very important acid is formed by the union of 1 atom of this element with 5 atoms of oxygen. When lime or potash is present, the ammonia produced by the putrefying substances is converted into nitric acid, and is decomposed; its hydrogen unites with 3 atoms of oxygen of the air and forms water, and its nitrogen with 5 atoms of oxygen to form nitric acid, which produces a salt called a nitrate. If the base present be lime, a nitrate of lime will be produced; if potash, nitrate of potash or nitre; if soda, nitrate of soda. This process is continually going on in nature, more especially in warm countries and in particular localities. The nitrate of potash is found in great quantities in the soil of some parts of India; and nitrate of soda, which has been so extensively used as a manure, is imported from Peru, where the supply is said to be inexhaustible. In both cases these salts are obtained by lixiviating (washing) the soil, and crystallizing the clear solution by evaporation. There can be no doubt that nitre is formed in all the rich soils of temperate climates, by the same natural process, though less abundantly. In the way above described, the whitewash of ill-ventilated apartments, and especially of stables,

where ammonia abounds, is often found to be converted into nitrate of lime; from this latter substance, nitre is easily produced by washing it in a solution of potash and evaporating the clear solution.

As nitrogen exists in all plants, and is a most necessary part of their food, the farmer must see the impolicy of excessive fermentation of his manure before he applies it to the soil, by which so much is wasted in the form of ammonia, as is sufficiently indicated by the strong smell which dung-heaps constantly emit. But of this more hereafter.

CHLORINE.

This is an abundant element in nature: its equivalent number is 36. In its gaseous or uncombined state, it is unrespirable and very suffocating and offensive to the lungs. United with 1 equivalent of hydrogen, it forms muriatic or hydrochloric acid; and common salt, or chloride of sodium, consists of 1 equivalent of this element united with 1 equivalent of sodium, the metallic base of soda. It destroys all vegetable colours, and is now generally used by manufacturers of cotton and linen fabrics for bleaching, for which purpose it is combined with lime, forming what is called bleaching powder. It is also the efficient principle in the liquid chloride of lime, so generally used to disinfect the foul air in sick rooms and unwholesome houses. Chlorine unites with metals and other substances, and forms those compounds called chlorides; but it is as a constituent of common salt, that it becomes important to agriculture, as it is found in all plants, and is therefore a necessary ingredient in all perfect manures.

SULPHUR.

This substance is too well known to need description: its equivalent number is 16. It is used in the manufacture of gunpowder and of fireworks, but its most valuable use is in making sulphuric acid. When burnt in the air, it unites with two atoms or equivalents of oxygen, to form sulphurous acid; but when burnt in close vessels with nitre, it unites with 3 atoms of oxygen, and forms sulphuric acid; the acid of the sulphate of lime or gypsum, from which plants chiefly derive their sulphur. It unites with metals, forming a class of substances called sulphurets, of which the common mineral called mundic or sulphuret of iron, is a familiar specimen. The gaseous combination of sulphur with hydrogen, called sulphuretted hydrogen, has been before mentioned. The sulphur of commerce is a volcanic product, and is brought chiefly from Italy.

PHOSPHORUS.

This is a very inflammable substance, and burns at the ordinary temperature of the air: its equivalent number is 12, and it unites with 2 equivalents of oxygen, to form phosphoric acid, which, with lime and magnesia, constitutes the phosphate of lime and magnesia, or bone-earth, so extensively used as a manure. Phosphorus, united with hydrogen, forms the light inflammable gas called phosphuretted hydrogen, sometimes seen burning in churchyards, "lingering and flickering near a new made grave," and in marshes, where it is known as Will-o'-the-Whisp.

The importance of phosphorus to agriculture

must be obvious, when it is considered that neither blood, flesh, nor bone, can be formed without it, and that consequently it is required in all the plants and fruits which serve as the food both of man and the inferior animals.

An element so essential to the support of animal existence, is accordingly very generally diffused; for not only is phosphate of lime found in all fertile soils, but also in all waters, whether those of the sea, or of springs. But though so extensively diffused, it is rarely found accumulated in great quantity, so as to render the mineral phosphate an article of commerce, and agriculture has to depend upon bones for its principal supply. Large masses have indeed been discovered in the south of Spain; but in situations of too difficult access, and too remote for convenient transport. It has been recently announced, that some of our limestones, particularly the lias, are very rich in this mineral, a fact which is likely to prove of the greatest importance to agriculture.

IRON.

This metal is of almost universal prevalence, as it is found in a mineral state in every part of the world. In many countries, vast mountain-masses are entirely formed of its ores, in which it exists as an oxide, though of various degrees of purity. The equivalent number of pure iron is 28, and it unites with 1 equivalent of oxygen, to form the black oxide, and 3 equivalents of oxygen unite with two equivalents of iron, to form the red oxide, in which state it affords the colouring matter of almost all soils and rocks, most of which, without its presence, would be perfectly white. In its

oxidized state, it exists in all plants that serve to sustain animals, and their existence every moment depends upon its presence in the blood. In the act of breathing, it is the means by which the oxygen of the air is conveyed to every part of the body;* and if it be vitiated by inhaling certain gases, of which sulphuretted hydrogen is one, life is instantly destroyed. It is needless to say anything of the uses of iron in the various arts, which are so general and indispensable, that none of them deserving the name could exist without it. The greater part of the iron ore found in England is mineralized with carbon, sulphur, silica, and alumina, from which it is separated by fluxing the ore in furnaces with lime and coal.

MANGANESE.

This is a metal of much rarer occurrence than iron, and is found only in very minute quantities in plants; so minute indeed, as to render the necessity of its presence somewhat doubtful. Its ore, the black oxide of manganese, is obtained from the mines of Cornwall and other places, and is much used in the arts, particularly in bleaching, and the colouring of glass, to which it imparts a delicate pink or purple colour.

Lime and magnesia, potash and soda, silica and alumina, are not elements, but oxides of metals, or metal-like substances, as before stated; but as they are always found in their earthy or oxidized state, and cannot be decomposed without the most powerful chemical agencies, it will be better to consider them as simple substances, in the form in which they occur to our notice.

* Liebig.

LIME.

This substance is called caustic alkaline earth: its equivalent number is 28, and combined with 1 equivalent of carbonic acid, for which it has a strong affinity, it forms carbonate of lime, or mild lime, in which state it exists in vast masses, forming mountain ranges in most parts of the world, and also those extensive coral reefs, so dangerous to mariners, in all the tropical seas. In its caustic state, (quick lime,) it is highly beneficial to land as a decomposing agent, and in its mild state is a constant ingredient in all fertile soils, as it not only furnishes a large part of the mineral food of plants, but is also a mechanical improver of the soil. We have almost pure specimens of carbonate of lime in the statuary and other crystalline marbles, and nearly so in chalk, and the shells of fish; but most of the limestones used in agriculture, contain more or less alumina, or the pure matter of clay, and the lias limestone contains so much as to render it when burnt, a good hydraulic lime, and is therefore used in building sea-walls, and the foundations of bridges, as the mortar made with it sets quickly, and soon becomes quite hard under water. When pure carbonate of lime is burnt in a kiln, all the carbonic acid is expelled; and if we consider, as stated above, that the equivalent of lime is 28, and that of carbonic acid 22, 50lbs. of pure limestone will lose 22lbs. by burning, or 44 per cent. The loss by burning will of course be less in proportion to the impurity of the stone. There is a kind of limestone which contains a large portion of magnesia; this is found

in some of the midland and northern counties, and is beneficial to land when applied in small quantities, but is injurious when used in the large way. All lime, while it remains in the caustic state, is hurtful to young plants, and the injurious effect experienced from the use of lime produced from magnesian limestone, is owing to its remaining a long time in the caustic condition, from the weak affinity of magnesia for carbonic acid.

Quick lime has a strong affinity for water. If 9lbs. of water be poured upon 28lbs. of lime fresh from the kiln, great heat is produced, and it speedily falls into powder, which remains quite dry, and becomes what is called a hydrate of lime, or slacked lime. In this state it still retains its caustic property, but by exposure to the air, it attracts from it carbonic acid which it had lost by burning, and returns to its former state of carbonate of lime, though in a pulverized condition. By this last operation the water is again expelled. Lime is composed of 1 equivalent of calcium, and 1 equivalent of oxygen.

MAGNESIA.

This substance has also obtained the name of an alkaline earth; and as it has been noticed as constituting with lime, the base or solid part of bone-earth, and as being associated with lime in some rocks, it is needless to dwell further upon it. Its equivalent number is 20, and in that proportion unites with 1 equivalent of carbonic acid, to form carbonate of magnesia. Magnesia is composed of 1 equivalent of magnesium and 1 equivalent of oxygen.

POTASH AND SODA.

These substances are called alkalies, and both play very important parts in the process of vegetation, and there is reason to believe that in many instances they are capable of supplying the place of each other; it is quite certain, however, that the presence of both is necessary to the fertility of soils. The equivalent number of potash is 48. The ashes of almost all plants contain this alkali, and therefore it is supposed to exist in them to serve as the basis of the vegetable acids, and to aid in those transformations which are carried on in the organs of plants. In union with silica, (the earth of flints,) it forms, as a silicate of potash, the hard external covering of the grasses, including those of the corn-bearing kind; and this substance is often found collected in a glassy mass amidst the ashes of a burnt hay-rick. Potash is a constituent of granite and other primitive rocks, from which it was doubtless originally derived. It is extensively used in the arts, and in medicine; with oil and fat, it forms soaps. United with flint-sand by fusion, it forms glass; and it combines as a base with various acids, to form a numerous family of salts. It has so strong an affinity for water, and holds it with such obstinacy, as to retain a considerable portion, even at a white heat. Potash is composed of 1 equivalent of potassium and 1 equivalent of oxygen.

Soda is the basis of common salt: its equivalent is 32. It has been observed before, that there is some doubt how far potash and soda may serve as substitutes for each other in the vegetable economy. Certain plants which, when growing on the sea-

shore, produce only soda in their ashes, in places remote from the sea, yield potash, and little or no soda. For the purposes of making soap and glass, in which it is more extensively used than potash, soda was formerly obtained from the ashes of sea-weed; it is now, however, extracted from common salt in large manufactories in the north of England, and produced at a much less expense. This new method of obtaining soda, and the circumstances attending it, forms a surprising instance of the rapid progress of the arts, aided by the light of scientific principles. Owing to the great improvement in this branch of manufacture, the trade-price of soda has been very much reduced. It should, however, be observed, that the crystallized carbonate of soda sold in the shops contains 10 equivalents of water, or 90 parts in 143, about 63 per cent. Both soda and potash unite in all proportions with silica, (flint sand,) to form glass. When silica much predominates, as when 3 parts of silica are fused with 1 of the alkali, in a glass-maker's furnace, a permanent glass is produced; but if the proportions be reversed, they yield a glass which dissolves in boiling water. Soda, like potash, is a constituent of some of the primitive rocks in which it exists, united with silica. Compact felspar, one of these rocks, sometimes contains 14 per cent. of this alkali. Soda is composed of 1 equivalent of sodium and 1 equivalent of oxygen.

SILICA.

This earth, which is sometimes called quartz, is perhaps the most abundant substance in nature, as it is the chief ingredient in all the older rocks, and

great mountain masses of the world, as well as of sea-sand, and forms by far the larger portion of most soils. Its equivalent number is 16. We have pure specimens of silica in rock crystal, and the glasses of the best spectacles are formed from pebbles of the same substance. From the tendency of silica to unite with alkalies by fusion, and even in a state of minute division when the alkali is dissolved in water, it has been ranked amongst the acids, and called silicic acid, and such combinations, silicates; it is likewise soluble in water containing carbonic acid, by the action of which, as well as of potash, it is thus rendered capable of being taken up by the roots of plants. Most mineral waters contain silica in solution, and the hot springs of Iceland deposit it in large quantities upon their margins. Besides the necessity of silica to form with potash the flinty coating of all the grasses, the permanent fertility of all soils depends in a great measure upon the presence of a due proportion of siliceous sand, of various degrees of fineness, which renders them permeable both to water and air, by counteracting the adhesiveness of alumina. Clay soils, which are sterile from their too great adhesiveness, yet contain much more silica than alumina, and even pipe-clay is composed of about equal portions of each of these earths. In both clay and sandy soils, which are derived from the disintegration or breaking down of the primitive rocks, silica exists in a state of chemical combination with potash, soda, and alumina, forming *silicates* of those substances. Silica is composed of 1 equivalent of silica with 1 equivalent of silicium.

ALUMINA.

Alumina forms a large portion of many rocks, and mixed with silica and siliceous sand, constitutes the greater part of extensive strata of the most fertile character in every country upon the globe. It gives the adhesive property to soils, by which they retain moisture and manure for the nourishment of plants. Those soils in which it most abounds are called clays. Pure alumina holds water with such tenacity that it retains half its weight of water at the temperature of 60° Fahrenheit. A soil totally destitute of alumina would be perfectly sterile, and one in which it is very deficient, is called a hungry soil, because it soon loses both water and manure by evaporation and percolation. The equivalent number of alumina is 18. Though alumina is never found in a state of absolute purity in nature, those beautiful gems, the ruby and the sapphire, consist almost entirely of it in a crystalline form. It forms the principal base of the well-known salt called alum, from a solution of which it may be separated in a pure state by an alkali which causes it to precipitate. It is scarcely needful to observe upon the immense importance of alumina in the arts. It constitutes the plastic principle of potter's and porcelain clays, and as the basis of alum is extensively used by dyers as mordant to set their colours. Alumina is composed of 1 equivalent of aluminum and 1 equivalent of oxygen.

The acids which have been mentioned; namely, carbonic, nitric, muriatic, sulphuric, and phosphoric, are called mineral acids, because they are commonly found united with mineral substances. When

they are chemically united with the oxides subsequently spoken of, potash, soda, lime, magnesia, oxide of iron, oxide of manganese, as well as many others, they form mineral salts, which have received names indicating the particular acid and base of which they are composed; viz. if carbonic acid be united to a base, it is called a carbonate of that base, as carbonate of lime, carbonate of potash, carbonate of soda, &c. If the acid be nitric, the salt is called a nitrate; if sulphuric, a sulphate; if phosphoric, a phosphate; thus making carbonates, nitrates, muriates, sulphates, and phosphates of the several bases. The names of the above salts will frequently occur in the course of this work; it will therefore be necessary to bear in mind their signification. In their perfect and separate state these salts take the form of crystals, whose shapes are constantly the same in each individual kind. Some of them in crystallizing unite in different proportions with water in a solid state, which is then called their water of crystallization. Sulphate of iron, sulphate of soda, and carbonate of soda present such instances. In some instances an acid unites with two different bases, and these form what are called double salts, as in the case of alum, which is a sulphate of alumina and potash.

CHAPTER II.

ON SOILS, HOW PRODUCED, AND THE CAUSE OF THEIR DIVERSITY.

HAVING given a brief account of the elementary substances which are connected with agriculture, we now proceed to the consideration of soils. As soils are the habitation of plants, and the magazine of their inorganic and mineral food, it will be desirable to take a comprehensive view of their nature and origin, in order to form correct ideas of their great diversity, the causes of their fertility or barrenness, and the means of rendering them more productive.

There is every reason to believe that all soils, however diversified in their composition, have been originally derived from the breaking down and decomposition of rocks. The most ancient rocks, those which form the foundation of all others, are unstratified: that is, they do not exist in layers, but in vast formless masses; some of these, called Trap* Rocks, evidently owe their present position to volcanic eruption in a fused or molten state, as they have fissured, penetrated, and overlaid many other rocks through which they have been forced. These rocks, by their partial destruction, furnished the materials for the succeeding sedimentary or stratified rocks, as is evident from the composition of the latter; and it is also evident that these materials were deposited by the action of water, like the sands of our tideways

* From *trappa*, a Swedish word, meaning a step, as in their overlying masses these rocks have sometimes the appearance of steps.

and sea-shores, and the sediment of ponds. These stratified rocks are seen in most mountainous countries resting in highly inclined positions on the sides of the more ancient rocks from which they have derived their materials, and together with them form all the highest mountains on the face of the globe; descending beneath all others, and also rising above them into the regions of perpetual frost, even under the equator. The rocks thus briefly described are all exceedingly hard, and for the most part crystalline, and afford no evidence of their having during their formation served as the habitation of either plants or animals. It is from the latter circumstance, and also their great age, that they are distinguished by the general name of *Primary Rocks.* The ores of the more valuable metals are generally found in the veins or fissures of this class of rocks.

From the above primitive masses have been produced, by the long continuance of destructive agencies, the vast accumulation of those which succeed and overlie them, and which are superimposed in strata or layers of great thickness, one over the other. According to the materials of which these strata are formed, they have hardened into rocks, or have formed beds of clay, which, by the outcrop of their edges, and the exposure of part of their surfaces, like tiles upon the roof of a house, form that great diversity of soils which the face of most countries exhibit. As these strata contain coal, lime, potter's clay, iron, gypsum, and rock salt, and form the most accessible as well as the most fertile parts of the earth, they are the best adapted to agriculture and the habitation of mankind. These rocks have, for the convenience

of studying them, been ranged under different groups or orders; but generally the greater part of them have been called *secondary*, to distinguish them from those called primary, as before mentioned: but the uppermost have received the name of *Tertiary Rocks*. In the language of geology, all the strata are called rocks, though many of them consist of soft clay. All the rocks of the two extensive classes above mentioned; namely, the secondary and tertiary, have evidently, like the stratified primary rocks, been deposited by, and formed under, water, on the bottoms of seas and lakes; and the vast quantity of shells and other fossil remains which they contain, affords the most unquestionable proof that during their deposition their surfaces have served as the habitation of successive tribes of numberless animals, some of enormous size, which must have lived, died, and been successively covered up where their remains are found.

It would appear that the whole of these strata suffered great disturbance and destruction during and after their formation, both from volcanic forces, and the action of water upon their surfaces; many of them are found dislocated, all more or less inclined, and some raised to almost a vertical position; while others rest unconformably upon the ruptured edges of those beneath. The deep furrows, or valleys, observable upon the surfaces of some of these strata, which were afterwards filled up, and those found on the present surface of the earth, plainly show that during their gradual elevation above the waters, under which they were formed, and also afterwards by sudden submergence, they must have been subjected to the

action of strong currents, or torrents of water, by which their materials have been moved and spread in extensive beds of gravel or earth, which are now found covering the other strata over large tracts of country, and which have received the name of *diluvium*, or *diluvial deposits*, and sometimes *drift*, or *gravel*.

The same causes, both mechanical and chemical, which effected the destruction of the older rocks and the formation of the newer strata, are still in operation, though perhaps in a less powerful degree. Volcanos and earthquakes still exert their destructive and desolating energy in many parts of the world; while, in all mountainous and hilly countries, the rocks are shattered by the action of frost, and their detached fragments being carried down by torrents produced by the melting of snow and by rain, are deposited in rolled stones and gravels, on the first levels beneath, while the finer particles are carried on by the streams, and form the *alluvial* beds of the valleys and plains which they water and overflow. As during great and periodical floods the waters of rivers are exceedingly turbid, an immense quantity of silty or finely divided matter is borne on to the sea, and deposited at the mouths of such rivers, and in the deep waters beyond, often forming extensive lands, called *deltas*, as at the mouths of the Nile, the Ganges, the Mississippi, and many other great streams.

Having taken this general view of the structure of the surface of the earth, and of the causes by which it has been effected, it will be necessary to pursue the subject farther, and to give a short description of at least the principal strata, in order

to show the intimate connexion of geology with agriculture, and the means such knowledge presents for its improvement. It has been observed that the strata overlie each other, much after the manner of the tiles on the roof of a house, exhibiting a greater or less proportion of their surface, and presenting bands of various breadths, from a few yards to many miles, and consisting of soils differing as wideiy as possible from each other. Though some countries exhibit many more strata than others, the order of their succession is constant: that is, with regard to all the secondary and tertiary strata. A rock or stratum of one kind which is found overlying another in one place is never found to underlie the same kind of rock in another. This order is not only ascertained by their constant relative position and external properties, but also by the fossil animal remains found in each, which differ more or less from rock to rock, and in those widely separated are entirely distinct. The prevalence of particular kinds of organic remains in each rock, and their succession, is so constant in every part of the world, as to enable a geologist to determine from a single hand specimen the rocks that lie both above and beneath, or, rather, its proper position in the series, its relative age; and, if we confine our views to England, the nature of the soil it affords, whether it be a light or a heavy soil, a stiff clay, a porous sand, or a calcareous and rubbly mixture; and even to point out by means of a geological map the surface which it occupies, and its line of direction.

Though the order in which the rocks overlie each is never reversed, the series is sometimes broken, so that a stratum which in one part of the

country presents a considerable surface, is in another part either absent or entirely overlaid, and the one above it is found to rest upon a lower and older member of the series. A knowledge of the rudiments, at least, of geology, affords a surer means of judging of the nature of the soil of any particular district, than any vague and loose description, such as is usually given, but also what facilities that and the neighbouring country affords for its improvement, by means of the application of lime, or marl, the mixture of soils, and draining. By way of explaining this, and giving a clearer idea of the subject, we shall proceed to give in the following chapter a brief account of the principal strata which form the soils of England and Wales, which offer a more extensive geological series than perhaps any other country of equal extent upon the face of the globe. We shall begin with the *tertiary*, or uppermost formations, and pursue the series of strata as they crop out and appear upon the surface, in following a west and north-west direction from London, which, it is remarkable, is situated upon the newest and uppermost of the *regular strata* of England, though there are some partial spots of very limited extent which claim a higher place in the tertiary order.*

* See Geological Section in the Appendix.

CHAPTER III.

GEOLOGICAL ARRANGEMENT OF THE SOILS OF ENGLAND AND WALES.

THE LONDON CLAY.

This stratum, to which London has given its name, surrounds it on all sides, extending over considerable portions of Middlesex, Essex, Surrey, Kent, Berkshire and Hampshire; its thickness has been found to vary from 70 to 700 feet in different localities. When dug through it presents an almost uniform bed of blue clay, and affords an excellent material for making bricks, and therefore forms a soil but ill adapted to arable purposes, which, with the requirements of London, has consigned the larger part of the surface to pasture. At London, and some parts of the neighbourhood, this stratum is extensively covered with thick beds of gravel; and at Hampstead, Highgate, and Bagshot, with a white and yellow sterile sand, with numerous pebbles, and commonly called the Bagshot sand. This clay, though unfavourable to cultivation by the plough, is rendered highly productive as garden land by spade culture and constant and heavy manuring.

THE PLASTIC CLAY.

This stratum underlies the London clay, and rests upon the chalk. It extends over portions of

Middlesex, Essex, Suffolk, Bucks, Berks, Hants, Wilts, Dorset, Surrey, and Kent. It is of various thickness, from 100 to 500 feet, and consists of numerous beds of clay, pebbles, and sand, the latter forming extensive tracts of poor heathy land in Hampshire and Dorset. The clay in many parts affords excellent materials for the potter, especially about Poole; but its agricultural character is inferior, as may be expected from so unfavourable a material. Detached masses of the plastic clay occur on the summits of the chalk hills, where the traveller is often surprised by the sight of brickkilns in the midst of a wide extent of chalk country. When this clay thins out, as in Berks and Wilts, pits are often sunk through it into the chalk, which afford an excellent top-dressing for the sour, cold, stiff soil on the surface, of which it is both a mechanical and chemical improver.

SECONDARY STRATA.

THE CHALK.

The chalk, the highest of this series, is one of the most extensive formations in England, reaching in an irregular and almost continuous line from Flamborough Head in Yorkshire to Sidmouth in Devon in one direction, and in another to Margate and Dover in Kent, occupying a very wide extent in Wilts and Dorset, as well as some other localities. It is often of great thickness; in one instance, at Inkpen, about 1,100 feet. The upper portion, which contains flints, affords but a poor thin soil, and is generally occupied by sheep

pasture; though in some parts it is covered with a hazel coloured soil mixed with flints, which well repays the labour of the skilful farmer, with the aid of the sheepfold and artificial manure. The lower beds of the chalk are marly, and afford very valuable wheat and bean soils, especially when the chalk marl blends with the green sand, which is the next stratum beneath.

THE GREEN SAND.

This stratum crops out from beneath the chalk and chalk marl, through the greater part of its extent, and varies from 100 to 300 feet in thickness. The upper beds near the chalk, often afford a good soil for most kind of crops, and in many situations is admirably adapted to the purposes of the market gardener, as at Biggleswade in Bedfordshire, and other places to the north and north-west of London. But in the lower portion, which is separated from the upper by a band of clay, and where distant from the chalk, as in Somerset and Devon, the soil is flinty, arid, and poor, and for the most part covered with heath. In Kent the green sand affords a rough limestone, which produces the brown lime used in London for forming concrete, and on the Blackdown in Somerset and Devon, a tolerable sandstone and the celebrated scythe stones. This stratum beneath the chalk and the plastic clay above it, afford striking instances of soils of the most opposite qualities, improvable by means of mixture, of which nature herself presents frequent instances along their adjoining lines.

THE WEALDEN CLAY.

This stratum, which is of great thickness, in some places upwards of 1000 feet, produces the cold wet clay *soils* of Surrey, Sussex, and Kent, which are better adapted to the growth of oak and other wood, than either to pasture or the plough. Under the plough the soil is heavy and expensive to work, and the pasture for the most part is very inferior from the retentive nature of the surface, and in neither case can be rendered tolerably fertile, but by a vigorous and judicious application of capital, in the way of draining and burning the clay, a means by which great triumphs remain yet to be achieved in agriculture. This stratum produces the shelly Petworth marble, seen in the shafts of some of our cathedrals, and also the Purbeck beds of stone.

THE IRON SAND.

This formation is the next in succession beneath the Wealden clay, and is generally associated with it by geologists. It is composed of a series of beds of reddish sand and sandstone, with occasional beds of clay, and forms portions of the counties of Kent, Sussex, Norfolk, Cambridge, Huntingdon, Bedford, Oxford, Wilts, and Dorset. It yields in some places ochre, and abounds so much in iron, as to have been resorted to by the ancient inhabitants of England for that metal. The iron sand is in some parts poor and covered with heath, but in the counties of Kent, Cambridge, Bedford, and Wilts, it affords some useful soils for garden and general cultivation, and in some parts of Kent produces hops.

THE OOLITES.

This series of rocks occupies a wide space of the middle part of England, extending from the mouth of the river Tees in the county of Durham, to the south coast in Hampshire and Dorset.

THE UPPER OOLITE,

consists of beds of imperfect limestone, resting upon a deep stratum of clay, called the Kimmeridge clay. The stone is often of superior quality for building purposes, as at Portland. The clay affords a wet heavy soil of expensive cultivation, and that above the stone is poor and thin, but at the junction of the two, from the mixture of calcareous matter, the soil is of easier cultivation and often very good.

THE CORAL RAG AND OXFORD CLAY.

This formation consists of two beds of imperfect limestone, called coral rag and calcareous grit, resting upon a very deep bed of blue clay, called the Oxford clay. The quarries of this stone produce the perishable building stone, formerly too much used in the public buildings at Oxford. The clay is too cold and wet for successful arable culture, and is therefore chiefly given to pasture, which, for the most part poor, cold, and backward, has some tolerable dairy lands in the several counties of which it occupies a part, as in Wilts, Gloucester, Oxford, Beds., &c. In most of the pasture land, however, in the winter months, the surface wears a repulsive appearance, from the wetness of the soil and the cold sour aspect of the herbage. This extensive stratum presents another

of those soils, in which the skilful application of a knowledge of scientific principles is destined to work a great improvement.

THE LOWER OOLITE,*

consists of several successive strata or beds of imperfect limestone, separated by others of greater or less thickness of clays, marls, and fullers' earth. These several beds of stone have received the names of Stonesfield Slate, Corn Brash, Great Oolite or Bath Stone, Inferior Oolite, and Lias. The clays are mostly in pasture, and are generally cold and wet with sour herbage, and require draining to make them tolerably productive. The soils on the Stonesfield slate and corn brash are tolerably productive under the plough, but upon the great oolite it is thin and poor, and often encumbered with large stones near the surface, which obstruct the plough. The calcareous sand of the inferior oolite affords tracts of fertile soil, adapted to every kind of crop; and in some parts, as in the centre of Somerset, carries fine orchards and valuable pastures, which are improved by marling. The great oolite produces the fine stone used in the buildings of Bath; and the inferior oolite, that used in the construction of Wells cathedral and Glastonbury Abbey; while the stone of these formations in the northern part of the kingdom are of a more sandy nature and of inferior quality.

The lias limestone is extensively burnt for agriculture, and affords excellent hydraulic lime for water-works; it abounds in fossil shells, parti-

* So named because composed of round particles, like the roe of fish.

cularly the remarkable kind called *Ammonites*, varying from half an inch to three or four feet in diameter; it also contains the fossil remains of numerous animals of the lizard species, called Saurians, and in some parts is very rich in phosphate of lime, derived from immense deposits of the dung of these animals. The recent discovery of great quantities of this fossil dung called coprolite, is likely to prove of the greatest importance to agriculture, in affording a future supply of phosphate of lime, a mineral portion of the indispensable food of plants, never too abundant, and generally very deficient in the soil.

All the oolitic strata above mentioned abound with fossil shells, and in some they are so numerous as to constitute almost the entire mass of the stone. Numerous beautiful valleys break through the nearly horizontal strata of the oolites, whose steep sides are generally clothed with woods, while their lower portions and well watered bottoms afford valuable pastures.

The lias, the last mentioned of this series of rocks, is the most extensive. The quarries exhibit the stone in horizontal layers, divided by the seams of marly clay. The upper beds are blue, and the lower of a greyish white. The hardest kind afford fine slabs for paving; and being capable of taking a good polish, are sometimes used for ornamental purposes, though it suffers much from long exposure to the weather, and therefore cannot be much commended as a building stone. The deep clays of this formation afford some good pastures when they have not been broken up, but generally the soil is cold and stiff, and on that account ill suited to the plough.

THE NEW RED SANDSTONE, OR RED MARL.

This formation extends from below Exeter in Devon, with some interruptions about Bristol, to Hartlepool, in the county of Durham. It spreads very wide in the midland part of England, and occupies a large portion of the counties of Devon, Somerset, Gloucester, Worcester, Warwick, Stafford, Cheshire, Lancaster, Leicester, Nottingham, Derby, York, and Durham, with a detatched portion in Cumberland. It consists of deep beds of red sand and marl, the sand generally underlying the marl. On the south coast of Devon, at Sidmouth, the abrupt cliffs exhibit a depth of at least 600 feet; and at Durham pits have been sunk into it to the depth of 708 feet. But in other places, as in Gloucester and Somerset, it thins out very much. The sands of this stratum abound in rolled stones or pebbles, and in Somerset and Devon contain large masses of them of every size, consisting of fragments of several different rocks of older date. Though the New Red Sandstone is almost destitute of organic remains, it is rich in brine-springs and rock-salt, which furnish the salt of Namptwich and Droitwich, it also abounds in Gypsum. Though the sands in some situations are very poor, and even sterile, they are generally fertile, and are cultivated with great skill, especially in the midland counties. The drifting sand of the forest of Sherwood in Nottinghamshire exhibits a striking instance of the triumphs of modern cultivation. The marls afford some of the most fertile and productive arable soils in the kingdom, and extensive tracts of rich meadow and pasture. This stratum is the most extensive in England, and

upon the whole is, perhaps, better cultivated and more productive than any other.

THE MAGNESIAN LIMESTONE.

This Limestone extends from Nottingham to Sunderland, cropping out from beneath the New Red Sandstone, and is by some geologists considered as the lower member of that rock. Its depth varies from 100 to 500 feet. The soil is generally thin, and of a chocolate colour, of moderate adhesiveness, and mostly inferior, but in many places capable of yielding good crops of all kinds of grain by the application of lime and high farming. The lime of this rock contains about 20 per cent. of magnesia, which renders it unfit for the use of the farmer; but excellent agricultural lime is found at no great distance through the greater length of this stratum. This rock affords the excellent building stone used in the erection of the Houses of Parliament.

THE COAL MEASURES.

These are more partial or detatched strata, occupying many parts of the kingdom west of the New Red Sandstone, from Northumberland to South Wales and Somerset, and consisting of numerous beds of hard clay, shale,* sandstone, and sometimes limestone, with numerous beds of coal, varying from a few inches to several feet in thickness. The sands which appear on the surface are poor and hungry; the clays afford a dark coloured, heavy, and wet soil, requiring draining, liming, and skilful management to render it profitable.

No profitable beds of coal are found anywhere

* Clay, nearly as firm as stone.

in England but in these Coal measures or to the east of the New Red Sandstone, though much expense has been incurred in seeking for it; they are, therefore, absent from all the south-eastern parts of the kingdom. Every kind of coal is undoubtedly of vegetable origin.

THE MILLSTONE GRIT.

This occupies a large space of country, often of great elevation, and is about 500 or 600 feet thick. It extends from Derbyshire to Northumberland, and consists of similar sands and shales to those of the Coal measures, which, for the most part, rest upon it. The sands are very poor, chiefly covered with poor pasture and heath, which afford but little encouragement to the improving farmer, while the shales have all the bad qualities of those of the Coal measures.

THE MOUNTAIN LIMESTONE.

This rock exists in detached masses in the West of England and South Wales, occupies a large space in Derbyshire, and forms extensive tracts in Yorkshire, Westmoreland, Cumberland, and Northumberland. It consists of very deep beds of reddish blue limestone, of excellent quality, sometimes divided by sandy and shaley layers. The soil is generally thin, but affords useful arable land, and sweet pasture both for sheep and cattle. It is highly improvable by heavy dressings of lime produced from the rock beneath, the effect of which is very durable, and, like marl, requires no repetition for many years. The districts of this limestone are generally elevated and exposed, and often traversed by deep valleys and fissures, as

in the Mendip Hills of Somerset, Clifton near Bristol, and Dovedale in Derbyshire, affording romantic and beautiful scenery. The lime is generally quite white, and well adapted both for building and agriculture, for which latter purpose it is extensively used in all the northern counties. This rock affords the beautiful secondary marbles of Derbyshire.

THE OLD RED SANDSTONE.*

This formation is generally very thick, in many places many thousand feet, and forms the larger portion of Hereford, Brecon, and Monmouth, and also detached portions of the east and north of Scotland. The soils consist of sands and marls much resembling those of the New Red Sandstone. The sand rock is, however, generally much harder, and in many places poor, and covered with heath; while, on the other hand, the marls afford, particularly in Herefordshire, deep pastures, productive orchards, and strong wheat and bean land.

SILURIAN STRATA.

The borders of England and Wales for the most part consist of a series of strata of great thickness, called by this name after the ancient inhabitants of those parts. Geologists have divided them into the Upper and Lower Silurian. The former consists of various beds of sandstone, shale, and limestone. They form generally very inferior soils of various consistence, but chiefly

* Geologists now associate the so-called Greywacke of Somerset and Devon, and the slates and slaty limestones of Cornwall, with the Old Red Sandstone, as containing the same organic remains or fossils, and denominate the whole the Devonian System.

consisting of cold clays. The limestone of this formation is extensively used both in Wales and the west of Shropshire, at Colebrook Dale, for the smelting of iron. The Lower Silurian Rocks consist of a stratum of sand from 2,000 to 3,000 feet thick, exceedingly sterile, and chiefly abandoned to heath, and beneath this sand of thick beds of sandy and earthy limestone, which afford some good soils in the county of Caermarthen. Upon the whole, the soils of this formation contrast very unfavourably with those of the Old Red Sandstone adjoining them.

THE CAMBRIAN SYSTEM.

This system of rocks, called also Greywacke * Rocks, are several thousand yards in thickness, and occupy almost all the western part of Wales, and parts of Somerset, Devon, Cornwall, and Cumberland. These tracts are for the most part hilly and mountainous, and afford a scanty pasture for sheep and goats; and, when cultivated, poor arable soils. There are, however, favourable exceptions. The Quantock Hills in Somerset along their lower portions present friable † soils, of easy cultivation and tolerable productiveness; and a crumbling rock of this system on the confines of Cornwall and Devon, locally called Shillot, yields the heaviest crops of the richest herbage, upon which cattle fatten with astonishing rapidity, and under the plough is too rich for the successful growth of wheat, as the crop falls, from its great abundance, before the ear fills. This rock affords

* Or Grauwacke, a German miner's name, and commonly given by Geologists to the lowest of the secondary rocks.

† Free-working.

the valuable roofing slates of Bangor, in North Wales, and Delabole, in Cornwall, as well as other places. It is also the first of the older secondary rocks, *according to our division, which contain fossil shells.*

THE PRIMARY ROCKS, OR THOSE WHICH CONTAIN NO ORGANIC REMAINS.

Clay Slate.—This Rock occupies a considerable portion of Cornwall, and is that in which the veins of tin and copper are chiefly found. The fragments of this rock exhibit a silky, shining surface, but mostly consist of very hard dark-coloured slates, and the soils it affords are very thin and poor, and the greater part of the surface lies for the most part waste, and often unenclosed. There are some detached portions of this rock in North Wales, the Isle of Anglesea, but it prevails most in Cumberland.

Mica Slate, and Gneiss.—These rocks occupy only very small portions of England, chiefly in the counties of Westmoreland and Cumberland, but form a large part of the west and north of Scotland. They are both of slaty and crystalline character, and form, throughout the greater part of their extent, elevated regions of almost hopeless sterility, consisting of stinted pasture and wild heaths, with here and there spots of some fertility in the valleys.

Trap Rocks, including Porphyry, Syenite,* Green-stone, Serpentine, Toad-stone, and Basalt. These are of inconsiderable amount in England,

* So named from Syene, in Upper Egypt, where this rock forms the cataracts of the Nile.

but occupy a considerable portion of the south of Scotland, where they are of a decomposing character, and containing potash, soda, lime, and magnesia, form soils of great fertility.

GRANITE.

This rock presents itself in England only in detached masses of no great extent, as at Mount Sorrel, .in Leicestershire, and different parts of Devon and Cornwall, from Dartmoor to the Land's End; it occupies, however, a large portion of Scotland. The soils produced by the crumbling of this rock are generally very hungry and poor, and ungrateful for cultivation, but in some partial instances, as at the extremity of Cornwall and in the Scilly Islands, are of tolerable fertility. This rock consists of a solid crystalline mass of three principal minerals, quartz, felspar, and mica, each differing greatly in size in different rocks. Some of them undergo no perceptible change for ages, while others, as in the instance of those of Cornwall, soon yield to atmospheric influence and the action of sea-water.

The above forms only a very imperfect description of the rocks which compose the soils of England and Wales, but will suffice to give some explanation of the great diversity which they exhibit, and their adaptation to the different purposes of agriculture. More correct notions of the extent of the different strata can only be obtained by means of a geological map, which can now be had at the small cost of five shillings, which marks with sufficient accuracy the extent of all the principal strata, with much even of minute detail.

Though the primitive rocks have furnished, by their partial destruction, all the materials of which the secondary and tertiary strata are composed, and which serve as the habitation, and supply the mineral food of plants, yet the several kinds of substances are very unequally distributed through these derivative masses, as we have seen in the great difference they present; some abounding so much in alumina as to constitute soft clays, others containing so much calcareous matter as to have hardened into solid limestone rocks; in some cases nearly pure, while in several the lime is more or less blended with silicious sand and alumina, forming that extensive class of impure limestone strata called Oolites; but the largest portion of these derivative strata consist of silicious sand more or less consolidated by means of finely divided matter, either of the same kind or of lime and alumina. Through all these masses, other substances of a less abundant kind, which form the remainder of the food of plants, are distributed in a more or less partial degree, causing that great variety, and often great disparity, observable in the productiveness of different soils.

The larger portion of the soils of most countries are derived from the gradual disintegration or decomposition of the rocks upon which they repose; and the quality of the soil varies with every change in the composition of the parent stratum beneath, both as to mechanical and chemical properties, embracing the two extremes of fertility and barrenness. Soils composed of either a pure sand, pure clay, lime or magnesia, must be equally unproductive; and on the other hand, those soils which are formed of the blended materials of all

the different strata, such as the extensive beds of diluvium, or drifted stuff, which often overlie and obscure the regular strata, and particularly alluvial deposits of rivers and tideways, are always the most productive, as they generally contain in abundance all the elements which form the mineral food of plants. It often happens that the near neighbourhood of strata and soils of the most opposite character afford the means of mutual improvement, and seem to be placed near each other as if to stimulate and reward the labours and skill of the farmer. The natural blending of these strata at their line of junction indicates the mode of improving each by mixture in places more remote, where they preserve their distinct character. Along the base of the chalk stratum, through a great extent of the south of England, the green sand crops out from beneath; and as the lower member of the chalk formation consists of a white or chalk marl, very fertile soils are always found where the materials of the two strata blend together, while, at a little distance, the chalk on the one hand, and the sand on the other, the soil is very inferior. Each is improved both mechanically and chemically by mixture. But these examples of the natural instances of the improvement of soils by mixture, both with regard to these and other strata, have been before noticed in the description of their geological arrangement.

We have mentioned the mechanical causes of the breaking down of rocks, and their reduction to the state of soils: chemical agencies are, however, also instrumental, and produce, perhaps, more extensive effect both on the rocks themselves and afterwards on the soils derived from them.

Water containing carbonic acid has a powerful effect in promoting the disintegration of rocks, and few of them can resist its action. This may be seen in the weathering, as it is called, of most building stones. The hardest marbles, when exposed to the weather, soon lose their polish, and in time become deeply corroded. This is owing to the presence of carbonic acid in rain water, which renders it a solvent of all limestones, and many of the hardest rocks yield gradually to the same influence. Granite consists of crystals of quartz, felspar and mica. Felspar, the principal constituent, is a very compound substance, consisting of silica and alumina, (the constituents of clay,) with minor portions of potash, soda, lime, and often oxide of iron. The four last readily yield to the solvent power of water containing carbonic acid, and by their separation the mass is broken down, and becomes clay, containing the quartz and mica in the state of coarse sand. The clay thus produced is that used in the manufacture of fine pottery and porcelain, and which is found in great abundance in Cornwall; and this decomposition of granite is no doubt the original source of the matter of all our agricultural and common clays. The quantity of the alkalies and lime contained in granite is very variable, and those granites which contain the most yield most rapidly to the effect of weather, while others remain for a long period apparently unaffected by it. The granite on the coast of Cornwall is exceedingly prone to disintegration, and the effect of the sea water, which contains a very large quantity of carbonic acid, exhibits a very striking instance of the combined effect of chemical and mechanical forces, as the

rocks upon that terrific coast are penetrated with caverns, and worn into a variety of wild and fantastic shapes. The celebrated Logan stone, and others like it, are rendered movable by the gradual wasting of the stone from the same causes; the central, or bearing part, being the least exposed, is the last to yield, and thus affords a point of support. In inland situations the same effect is observable, and large surface blocks of many tons weight present a rounded or pudding shape, from the long continued action of rain. Silicious, or flint sand, in a state of minute division, is incapable of resisting the solvent power of water aided by carbonic acid, so that soils are continually undergoing further disintegration, which is promoted by ploughing, harrowing, hoeing, and all the operations by which the soil is exposed to the weather in fallowing and the cultivation of fallow crops. The effect of water containing carbonic acid is very remarkably shown in the caverns of limestone rocks, from the roofs of which pendant masses of carbonate of lime, called stalactites, are seen, often extending to the floor, and forming large pillars of stone, while the sides and floors of such caverns are generally covered with the stony matter, which, though identically the same, has received the name of stalagmite. The cause of these stony incrustations is easily explained. The rain which falls upon the surface of the rock above is already charged with carbonic acid, which it has collected in its passage through the air, and in passing through the vegetable mould which generally covers the rock, receives an additional supply; thus charged with carbonic acid, it becomes a solvent of the limestone, as before mentioned,

and dissolves the rock through which it passes to the cavern beneath; being there exposed to the action of the air, every drop as it evaporates leaves behind the stony matter, which thus accumulates upon the roof, sides, and floor of the cavern. The petrifying effect of all springs which flow from limestone rocks is produced in the same way. The waters which flow from them soon lose by agitation and exposure to the air the carbonic acid which enabled it to dissolve the stone, and this, with the aid of evaporation, causes the deposition of the carbonate of lime upon the substances over which it passes, and in the bottoms of pools supplied by it. Some very ancient temples in the south of Italy are built of the stone thus deposited by the waters of a lake in the neighbourhood, which stone is there called travertine. It is chiefly owing to this chemical action of carbonic acid on rocks that soils have been produced, and still continue to yield their fertilizing mineral contents, which is promoted by every fall of rain, and every new exposure of the soil to the action of the air, by which carbonic acid is generated in the decaying substances it contains.

It is hoped that the explanation of origin and general nature of soils will enable the reader to form correct ideas of them and of the means of their improvement. The subject will receive further illustration when we proceed to treat of the physical and chemical properties of soils.

In the Supplement will be found a Table of the Series of British Rocks, including some of minor importance not here mentioned.

CHAPTER IV.

THE MECHANICAL AND CHEMICAL COMPOSITION OF SOILS, WITH ANALYSES OF SEVERAL KINDS, SHOWING THE CAUSE OF THEIR PRODUCTIVENESS AND STERILITY.

IF a quantity of soil be burnt, a portion of it will be dissipated and lost, but generally the larger part remains unchanged; the former is the organic part of the soil, and the latter the inorganic, or mineral portion, which in all fertile soils is always the most considerable. The organic matter has been deposited by plants and animals, which have grown, lived, and died, and left their remains upon the soil, or has been conveyed to the soil in the form of manure. It is the organic matter which gives to the surface-soil of grass lands its black colour, and frequently friable character. This organic matter is always in a state of gradual decay, and is called humus. An excess or deficiency of this partially decayed matter is alike unfavourable to fertility; in the former case by rendering the soil too light for the retention of water, and in the latter from a deficiency of organic food required by plants, particularly in the earliest stages of their growth. In peat lands it is always in great excess, forming from 50 to 70 per cent. of the whole; in arable soils it is very commonly deficient from defective management in the rotation of crops, or the want of a due supply of manure, while in old pasture lands,

and well manured gardens, it is abundant, but seldom in excess. The use of humus or organic matter in the soil is twofold—it attracts moisture and ammonia from the atmosphere, and yields by its decay a continual supply of both carbonic acid and nitrogen in the form of ammonia to the growing plants, before their leaves are sufficiently developed to obtain these substances from the atmosphere. This decaying vegetable matter also contains the inorganic or mineral substances of the plants from which it is derived, which, as fast as it is liberated by the progress of decay, forms an available and essential part of the food of the young plant, while its powers of collecting mineral food from the mass of the soil is limited and feeble. Such are the effects of humus, and of farm-yard manure, which, by its decay, supplies a rich humus to soils in which it is deficient.

The earthy, or inorganic matter, which remains after the soil has been burnt, consists of two parts —the salts, which are soluble in water, and the earths, which are insoluble. If a certain quantity of the soil be mixed with water, and well stirred, and then suffered to stand for some time, the grosser and insoluble parts will subside; when the water has become quite clear, if it be poured off and evaporated, a small deposit will be left, which generally consists of several different kinds of salts: chiefly common salt, sulphate of soda, gypsum, with nitrates of potash, soda, and lime, and a very small amount of chlorides, which constitute the greater part of the mineral food of plants. The insoluble part of soil, which is seldom less than 95 per cent. of the whole, consists of stones, sand, and finely divided matter, in very

variable proportions, which determine the loose or adhesive nature of the soil. The proportion of these may be ascertained by mixing the soil again with water, allowing it to stand for a short time, to permit the heavier matter to subside, pouring off the turbid water, and then suffering it to remain till the whole of the finely divided matter has subsided. This finely divided matter is called clay, though it generally contains carbonate of lime and other insoluble earths. These insoluble parts being dried and weighed afford a certain means of giving to soils a more definite character than is generally conveyed by the vague terms now in use, or of at least arranging them with some degree of order, under certain denominations. Those adopted by farmers will, however, suffice, if they are applied with more precise discrimination. The term sandy should not be given to a soil, unless it contains at least seven-eighths of sand; and those sandy soils which effervesce much with acids, should be called calcareous sandy soils, to distinguish them from those which are merely silicious. The term clayey soil should not be applied to land which contains less than one-sixth of impalpable, or finely divided matter, not considerably effervescing with acids. The name of loam should be confined to soils containing at least one-third of impalpable earthy matter, much effervescing with acids; and a soil to be called peaty, should contain at least one-half of vegetable matter. As, in general, soils are derived from the rocks or strata upon which they repose, and partake, more or less, of their nature, except where they are covered with drifted materials, such as gravel and sand, they may be distinguished by naming the particular rock, which

will always have great significance with intelligent agriculturists. Thus, as the case may be, the soil may be called a granite or green stone, a basaltic or greywacke soil, a new red sandstone sand or clay, a mountain limestone soil, a coal-measure clay, &c. These modes of distinguishing soils were suggested by Sir Humphrey Davy, who has given the following analysis of the composition of some soils which came under his investigation, and which afford very accurate notions of their mechanical composition.

I. A fertile soil on the banks of the river Parret, in Somersetshire, afforded eight parts of finely divided matter, and one part of silicious sand; and the finely divided matter gave the following result:—

360 parts of carbonate of lime,
25 alumina,
20 silica,
8 oxide of iron,
19 vegetable, animal, and saline matter.

II. A rich soil in the neighbourhood of Evesham, in Worcestershire, afforded three-fifths of fine sand, and two-fifths of impalpable matter; the latter consisting of—

35 alumina,
41 silica,
14 carbonate of lime,
3 oxide of iron,
7 vegetable, animal, and saline matter.

III. A specimen of good soil from Teviotdale afforded five-sixths of fine siliceous sand, and one-sixth of impalpable matter, which consisted of—

41 alumina,
42 silica,
4 carbonate of lime,
5 oxide of iron,
8 vegetable, animal, and saline matter.

IV. A soil yielding excellent pasture, from the valley of the Avon, near Salisbury, afforded one-eleventh of coarse silicious matter, and the finely divided matter consisted of—

7 alumina,
14 silica,
13 carbonate of lime,
2 oxide of iron,
14 vegetable, animal, and saline matter.

V. A good turnip soil from Holkham, Norfolk, afforded eight parts out of nine of silicious sand, and the finely divided matter consisted of—

63 carbonate of lime,
15 silica,
11 alumina,
3 oxide of iron,
5 vegetable and saline matter,
3 moisture.

In the above analyses the saline matters are not particularized; nor were they, at the period when the illustrious chemist investigated the subject of agricultural chemistry, thought of that importance to the fertility of soils which they are now known to be. There can be no doubt that the fertility of soils is very much influenced by the proportions of fine and coarse materials. A very large proportion of alumina (the adhesive principle of clay) would be unfavourable to fertility from its rendering a soil so stiff and untractable as to prevent the air from having due access to the roots of the plants, and too close to admit the roots to spread in search of their food. In wet seasons a very adhesive soil not permitting the superfluous moisture to sink into the subsoil, the temperature is kept down by evaporation from the surface. Such soils are, therefore, very properly called cold. On the other

hand, if a soil contains an excess of coarse materials or sand, it will be unproductive from its want of power to retain a sufficiency of moisture, as is seen in some situations where the soil is too dry to support any kind of vegetation, or at best but stunted heath. A soil of this description is generally called hungry from its incapability of retaining the manure applied to it, which is soon washed below the reach of the roots, or dissipated in the air. A large quantity of finely divided matter will not render a soil too adhesive if it consist chiefly of carbonate of lime and vegetable matter, as is exemplified in the soil No. IV. of the preceding analyses. In all cases the fertility of soils is greatly influenced by the nature of the subsoil, or the natural drainage, and either of the two extreme cases would in a great measure be corrected by resting upon a subsoil of opposite character.

A small quantity of finely divided matter will render a soil fit for the production of turnips, barley and oats, though more than 11 parts in 12 of sand in a soil would scarcely sustain a useful course of crops of any kind; the soils of barren heaths often contain less than 1-20th part of finely divided matter. The fertility of soils is very much affected by climate, and the quantity of rain they annually receive. A sand which in England, where much rain falls, would be productive, would in the centre of Europe be perfectly sterile from deficiency of moisture and the greater heat of the summers; and the difference is felt in a minor degree between the eastern and western parts of England, the quantity of rain which falls in some of the western counties being more than twice as

much as on the low level lands of the east, where the heat, and consequently the evaporation, is greater. As a general remark upon the earthy composition of soils, it may be stated that it is in vain to attempt by the ordinary application of manure to render productive either such as are too loose and open, or too adhesive to fulfil the mechanical conditions of fertility, the perfection of which lies between the opposite extremes of both. Such defects can only be corrected by changing, by means of artificial mixture, the proportions of the ingredients of the soil; that is, by the addition of sand to the adhesive soil, and clay or marl to that which is too open from excess of sand. Connected with this subject is the property of soils to absorb moisture from the atmosphere in dry weather, or during the intervals of rain. This property depends upon two conditions; first, the state of division of the parts of a soil; and, secondly, the nature of the materials of which it is composed. The same soil in a compact and firm condition, and in an open and divided state will absorb very unequal quantities of moisture, and it must be evident that these opposite states will have a very considerable effect upon the growth of cultivated plants. It is chiefly owing to this property of soils of absorbing moisture from the air that the operation of hoeing, by which the land is kept open, always proves so beneficial. When, by thus opening the soil, the air freely penetrates beneath the surface, the moisture it contains is attracted by the substances in the soil, as well as condensed by the coolness of the mass. The different substances of which soils are composed attract moisture with different degrees of

force; vegetable substances are more absorbent than animal substances; the latter more than clay, and clay is more absorbent than carbonate of lime. The power of soils to absorb moisture from the air has a very considerable influence upon their fertility, for by this means plants are supplied with water during the period of droughts, and those soils are generally the most fertile which possess this property in the highest degree; these are found to be such as contain a due mixture of sand, clay, carbonate of lime, and vegetable and animal matter which are easily kept open, and when in that state present the greatest quantity of internal surface to attract and retain moisture. Though clays, when once separated or pulverised as it is called by farmers, are very absorbent, this state of clay cannot, however, be attained without considerable expense, nor thoroughly effected without the aid of frost, or of rain succeeding very dry weather, and even then it soon loses its open condition by the least excess of water, after which, by the renewal of dry weather, it cakes and becomes too compact for the admission of atmospheric moisture by absorption. Carbonate of lime, and vegetable and animal matter improve the absorbent property of a soil without giving it adhesiveness; sand corrects adhesiveness without directly increasing absorbent power, though it renders the soil more open for other substances to act. As soils which possess the most absorbent power are the most fertile, this property affords one test of their comparative value easily available; by drying a small portion of the soil at the temperature of boiling water, and then exposing a certain weight of it to the action of the

air and observing the increase of weight by absorption in a given time. Sir Humphrey Davy found that 1,000 grains of a very rich soil containing much carbonate of lime and vegetable matter, dried at the temperature of boiling water, when exposed to the air at the temperature of 62°, gained, in an hour, eighteen grains. Another rich soil gained sixteen grains; a soil of less value thirteen grains; a fine sand eleven grains; an inferior coarse sand eight grains; and the sterile sand of Bagshot Heath, only three grains.

There is another property of soils which is of great importance to the farmer; that is, the power of preserving animal and vegetable substances; and consequently manures by chemical attraction. This power is possessed by clay, and, in a less degree, by carbonate of lime, by which they prevent the too rapid decomposition of those substances, and slowly yield them to the growing plant. While sandy soils, which have but little power of this kind, and soon lose the effect of the manure applied to them, clays and marly soils continue to make a grateful return for a much longer time. It is owing to this chemical property of clay and marl that they are used in making compost with stable and farm-yard dung, which experience has shown prevents the latter from being wasted by excessive fermentation and decay.

The colour of soils has much influence upon their power of promoting vegetation; dark coloured soils become heated much more rapidly than those of a light colour, which must have the effect of forwarding the germination of seed and the growth of plants, especially in their earlier stages, while the earth is yet exposed to the rays of the sun. A rich

black mould exposed to the sun, gains more than four times as much heat as a white chalk soil will do in the same time; on the other hand, the dark soil during the night, parts with its heat by radiation much more rapidly than one of light colour, and consequently sooner begins to condense and imbibe the moisture of the air. On this subject Sir H. Davy observes, "When soils are perfectly dry, those that most readily become heated by the solar ray, likewise cool most rapidly, their power of losing heat being greatest; but I have ascertained by experiment, that the darkest coloured dry soil, (that which contains abundance of animal or vegetable matter, substances which most facilitate the diminution of temperature,) when heated to the same degree, provided it be within the common limits of solar heat, will cool more slowly than a *wet* pale soil entirely composed of earthy matter."

"I found that a rich black mould which contained nearly a quarter of vegetable matter, had its temperature increased in an hour, from 65° to 88° by exposure to sunshine; whilst a chalk soil was heated to only 69° under the same ciscumstances; but the mould removed into the shade where the temperature was 62°, lost in half an hour 15°; whereas the chalk, under the same circumstances, had lost only 4°."

"A brown fertile soil, and a cold barren clay, were each artificially heated to 88°, having been previously dried; they were then exposed to a temperature of 57°; in half an hour the dark soil was found to have lost 9° of heat; the clay had lost only 6°. An equal portion of the clay containing moisture, after being heated to 88°, was exposed in a temperature of 55°; in less than a

quarter of an hour, it was found to have gained the temperature of the room. The soils in all these experiments, were placed in small tin plate trays two inches square, and half an inch in depth, and the temperature ascertained by a delicate thermometer."

The colour of a soil is therefore no unimportant consideration in forming an opinion of its relative value to the farmer, when all other things may be equal. By the presence of heat in the soil, the decomposition of the vegetable and animal matter and their solution, and that of the mineral food of plants, are promoted; and by the same agency, the pores and vessels of roots are expanded to imbibe and transmit the sap for the nourishment and increase of plants.

Seeing that the fertility of soils is so much affected by their physical or mechanical properties, or the mixture and proportion of their principal component parts, sand, clay, and carbonate of lime, as well as humus or peat, and considering the great defects of many soils in this respect, it must be evident that the artificial melioration by mixture, wherever the means are at hand, lies at the root of all permanent improvement of land, and will in numerous cases amply reward a larger expenditure of capital. Such improvement might be effected without risk; as when any doubt exists as to the result, experiments might be made on a small scale, to test the advantage, before an extensive outlay be incurred. This mode of improvement has been before alluded to; it cannot, however, be too much enforced, wherever the means and opportunity are available for the purpose.

CHEMICAL PROPERTIES OF SOILS.

If we consider soils in reference to the plants they support, it will be obvious that they exercise very various functions in the office of sustaining them. They serve as a habitation for plants, and a firm mass in which they can fix their roots, and support themselves in an erect position; they contain the mineral substances which form an essential part of their food; they attract oxygen and ammonia from the atmosphere, and serve as a magazine of vegetable and animal matter or humus; a recipient and reservoir of water, and a laboratory in which needful chemical changes take place, and the various substances both organic and inorganic are dissolved, preparatory to their entering the roots of plants.

In speaking of the mechanical properties of soils in the last section, we have noticed those substances chiefly which constitute their principal bulk, namely, sand, clay, lime and magnesia with humus. These are all tangible and visible substances. All the substances found in the ashes of plants when they are burnt, must have existed in the soil, either in the state in which they present themselves, or in their elements, though many of them are dispersed through the mass of the soil in quantities too minute to be detected by ordinary inspection, and can only be separated and ascertained by most skilful chemical operations; that is, by analysis. The most able scientific chemists have, within the last half century, devoted great labour to the analysis of soils, and the ashes of the plants they produce; and the result of these investigations has been the establishment of the fact, that those

mineral elements which the ashes of the plants contain, are constantly found in the soils that produce them, and that without their presence in the soil the plant could not have been brought to perfection. These mineral substances of the ashes of plants exist in soils in very variable proportions, and the fertility or barrenness of soils is in a great measure owing to their abundance, scarcity, or total absence of some or all of them.

The following analysis will exemplify the intimate relation which exists between the chemical properties or mineral substances of soils, and the plants which grow upon them, and how much the fertility of the former is influenced by their containing in some form or other, and in sufficient quantity, the elements contained in the ashes of the latter. These analyses of soils are given by Sprengel, an eminent professor of agricultural chemistry in Germany, with his observations upon their productiveness or sterility. Such analyses can be made only by professional chemists, and therefore it is useless to describe to the practical farmer the means by which they are effected. When the analysis of the subsoil is given, it is distinguished by being headed *sub.*

1. Analysis of a very fertile alluvial soil, which had borne crops of corn for seventy years without being manured, and with only an occasional fallow.

A small quantity of coarse silicious sand was first separated by the sieve, and 100,000 parts of the remainder produced the following result:—

Silica and fine siliceous sand	64.800
Alumina	5.700
Peroxide of iron	6.100
Peroxide of manganese	0.090
Lime	5.880
Magnesia	840
Potash principally combined with silica	210
Soda in a similar state	393
Phosphoric acid combined with lime	430
Sulphuric acid in the same state	210
Chlorine in common salt	201
Humus soluble in alkalies	2.540
Carbonic acid combined with lime	3.920
Humus	5.600
Nitrogenous matter	1.582
Water	1.504
	100.000

The subsoil retains the same composition as the surface-soil for a depth of six to twelve feet, so that it may be considered inexhaustible. When one portion of the soil is rendered unfitted for use, the inferior layers are brought up to the surface.

2. A good loamy soil from the vicinity of Gandersheim. It is remarkable for producing very fine red clover, when manured with gypsum. 100 parts contain—

		SUB.
Silica with fine siliceous sand	91.331	93.883
Alumina	1.344	1.944
Peroxide of iron, with a little protoxide	1.562	2.226
Peroxide of manganese	0.082	0.320
Magnesia and silica, in combination with sulphuric acid and humus	0.800	0.720
Magnesia, with silica, and humic acid combined	0.440	0.340
Potash in combination with silica	0.156	0.105
Soda principally in combination with silica, and a little as common salt	0.066	0.060

		SUB.
Phosphoric acid	0.098	0.190
Sulphuric acid in combination with lime	0.111	0.012
Chlorine, in common salt	0.012	0.012
Humus, with traces of azotized matter	4.100	0.184
	100.000	100.000

An inspection of the above analysis will show that the soil contains a very small proportion of salts of sulphuric acid—a circumstance which accounts for the favourable action of gypsum (sulphate of lime) upon it in the production of clover, in the ashes of which gypsum abounds.

3. A fine-grained loamy soil from Gandersheim, distinguishable for the large crops of beans, peas, tares, &c. which it produces when manured with gypsum. 100 parts contain—

		SUB.
Silica with fine siliceous sand . . .	90.221	92.324
Alumina	2.106	2.262
Peroxide and protoxide of iron . .	3.951	2.914
Peroxide of manganese	0.960	2.960
Lime, principally combined with phosphoric acid and humus . . .	0.539	0.532
Magnesia with silicate of potash, &c.	0.730	0.340
Potash	0.066	0.304
Soda	0.010	a trace
Phosphoric acid	0.367	0.122
Sulphuric acid in gypsum	a trace	0.010
Chlorine, in common salt	0.100	0.004
Humus and azotized matter . . .	0.900	
Loss	0.140	0.228
	100.000	100.000

The analysis of this soil shows that, with the exception of gypsum, every ingredient is present which is requisite for the nourishment of legu-

minous plants; hence it is that gypsum exerts such a favourable influence upon it.

4. A strong loamy sand from Brunswick. 100 parts contain—

		SUB.
Silica with coarse siliceous sand	95.698	96.880
Alumina	0.504	0.890
Peroxide and protoxide of iron	2.496	1.496
Peroxide of manganese	a trace	a trace
Lime.	0.038	0.019
Magnesia	0.147	0.260
Potash and soda, the greatest part in combination with silica	0.090	0.079
Phosphate of iron	0.164	0.110
Sulphuric acid, in gypsum	0.007	a trace
Chlorine, in common salt	0.010	a trace
Humus	0.846	0.226
	100.000	100.000

This soil was much improved by manuring with lime and ashes. It was then found well fitted for clover, beans, and peas.

5. A loamy sand from the environs of Brunswick. Analysis of the subsoil at the depth of three feet. 100 parts contained—

		SUB.
Silica and fine siliceous sand	94.724	97.340
Alumina	1.638	0.806
Protoxide and peroxide of iron with manganese	1.960	1.201
Lime	1.028	0.296
Magnesia	a trace	0.095
Potash and soda	0.077	0.112
Phosphoric acid	0.024	0.015
Gypsum	0.010	a trace
Chlorine of the salt	0.207	a trace
Humus	0.512	0.135
	100.000	100.000

This soil produces luxuriant crops of lucerne

and sainfoin, as well as of all other plants, the roots of which penetrate deeply into the ground. The reason is apparent—the subsoil contains magnesia, which is wanting on the surface-soil.

6. A loamy sand from the environs of Brunswick. Analysis of the subsoil at the depth of two feet. 100 parts contain—

		SUB.
Silica with coarse siliceous sand	95.843	95.180
Alumina	0.600	1.600
Protoxide and peroxide of iron	1.800	2.200
Peroxide of manganese	a trace	a trace
Lime in combination with silica	0.038	0.455
Magnesia in ditto	0.006	0.160
Potash and soda	0.005	0.004
Phosphate of iron	0.198	0.400
Sulphuric acid	0,002	a trace
Chlorine	0.006	0.001
Humus soluble in alkali	1.000	
Humus insoluble in alkali	0.502	
	100.000	100.000

This soil is characterised by its great sterility—white clover could not be made to grow upon it. The obvious cause of its poverty is a deficiency of lime, magnesia, potash, and gypsum; for we find that the fertility of the soil was much increased by manuring it with marl. The white clover, which formerly refused to grow upon this soil, now grew with great luxuriance: the aridity of the soil could not have been the cause of its poverty, for the stiff nature of the subsoil on which it rested prevented a deficiency of moisture.

7. A loamy sand from the environs of Brunswick. The analysis of the subsoil at a depth of two feet. 100 parts contain—

		SUB.
Silica with fine siliceous sand . . .	94.998	96.490
Alumina	0.610	1.083
Protoxide and peroxide of iron . .	1.080	1.072
Peroxide of manganese	0.268	0.400
Lime in combination with silica . .	0.141	0.182
Magnesia ditto ditto . .	0.208	0.205
Potash ditto ditto . .	0.050	0.070
Soda ditto ditto . .	0.044	0.050
Phosphate of iron	0.086	0.030
Gypsum	0.041	0.005
Common salt	0.004	0.003
Humus soluble in alkalies	0.400	0.015
Humus accompanied by azotized matter	2.070	
Resinous matter.	a trace	
	100.000	100.000

This soil is by no means remarkable for it sterility, but is decidedly improved by manurin with burned ferruginous loam. It is, howeve rendered much better by the use of burned ma —a manure which is rich in iron, potash, gypsun and phosphate of lime: the marl does not exert s favourable an action when applied in its natur state; but the heat liberates the potash from th insoluble compound which it forms with silica.

8. A loamy sand from Brunswick. Analysis c subsoil at a depth of one foot and a-half. 10 parts contain—

		SUB.
Silica with fine siliceous sand . . .	92.900	96.414
Alumina	0.820	1.000
Protoxide and peroxide of iron . .	1.666	1.370
Peroxide of manganese	0.188	0.240
Lime in combination with silica . .	0.748	0.364
Magnesia ditto ditto . .	0.168	0.160
Potash ditto ditto . .	0.065	0.045
Soda ditto ditto . .	0.130	0.082
Phosphate of iron	0.246	0.043

		SUB.
Sulphuric acid contained in gypsum .	a trace	0.005
Chlorine	a trace	0.007
Humus soluble in alkalies	0.764	0.270
Humus with azotized organic remains	2.225	
	100.000	100.000

This soil when manured with gypsum is very favourable to the production of leguminous plants and red clover. But it is very remarkable on account of the rust which always attacks the corn-plants which may be grown upon it. This rust and mildew is a disease which attacks the stem and leaves, and is quite different from the brand which appears upon the seeds and organs of reproduction. Rust is most frequently detected on plants growing on soils which contain bog ore, or turf-iron ore. According to Sprengel, rust contains phosphate of iron, to which this chemist ascribes the origin of the disease. It is very possible that other causes may operate in the production of similar diseases.

9. A fine-grained loamy marl, from the vicinity of Schoningen. It produces corn, which is, however, very liable to blight. 100 parts contain—

Silica with siliceous sand	93.870
Alumina	1.248
Protoxide and peroxide of iron . .	1.418
Peroxide of manganese	0.360
Lime, principally carbonate . . .	0.546
Magnesia ditto	0.560
Potash with silica	0.050
Soda and silica	0.040
Phosphate of iron	0.246
Sulphuric acid with lime	0.027
Carbonic acid, with lime and magnesia	1.145

Humus soluble in alkalies	0.400
Humus	0.090
	100.000

It will be observed that a considerable quantity of phosphate of iron is contained in this soil, and the corn which grows upon it is, as in the former case, disposed to rust.

10. A loamy soil from Brunswick, remarkable on account of producing buck-wheat, which is exceedingly poor in the grain. Analysis of the subsoil one foot and a-half from the surface. 100 parts contain—

		SUB.
Silica with coarse siliceous sand . .	95.114	92.458
Alumina	1.080	2.530
Protoxide and peroxide of iron . .	1.900	2.502
Protoxide and peroxide of manganese.	0.320	0.920
Lime in combination with silica . .	0.380	0.710
Magnesia ditto . .	0.300	0.551
Potash with silica	0.020	0.120
Soda	0.004	0.034
Phosphate of iron	0.052	0.175
Sulphuric acid with lime	0.006	a trace
Chlorine, in common salt	0.005	a trace
Humus soluble in alkalies	0.619	
Humus	0.200	
	100,000	100,000

By manuring the land with wood ashes, the soil is enabled to produce buck-wheat, with rich grain. The leguminous plants also thrive luxuriantly upon it. This increased fertility is due to the ashes, by means of which both potash and phosphates are supplied to the land.

11. Subsoil of a loamy, sandy soil, from Brunswick. It is remarkable for having produced ex-

cellent crops of hops for a long series of years. 100 parts by weight contained—

Silica and siliceous sand	95.660
Alumina	1.586
Protoxide and peroxide of iron	1.616
Peroxide of manganese	0.240
Lime in combination with silica	0.083
Magnesia	0.080
Potash	0.030
Soda	0.220
Phosphoric acid	0.039
Sulphuric acid	0.003
Chlorine	a trace
Humus soluble in alkalies	0.080
Humus	0.360
	100.000

Although the hops contain a large quantity of potash, soda, phosphoric acid, sulphuric acid, lime, and magnesia, yet we do not find that these exist in the soil in superabundant quantity. Nor is it necessary that they should, for the roots of the hops penetrate eight or ten feet deep into the soil, and search out the materials fitted to nourish the plants. Hence it is that hops thrive well on soils comparatively poor in their proper ingredients. The same is the case with all plants of a similar nature, the roots of which possess a tendency to extend in search of food. We see this particularly in lucerne and sainfoin.

SOILS OF HEATHS.

12. Soil of a heath converted into arable land, in the vicinity of Brunswick. It is naturally sterile, but produces good crops when manured with lime, marl, cow-dung, or the ashes of the heaths which grow upon it. . . . . .

Silica and coarse siliceous sand	71.504
Alumina	0.780
Protoxide and peroxide of iron, principally combined with humus	0.420
Lime ditto	0.134
Magnesia ditto	0.032
Potash and soda, principally as silicates . .	0.058
Phosphoric acid, principally as phosphate of iron	0.115
Sulphuric acid, in gypsum	0.018
Chlorine, in common salt	0.014
Humus soluble in alkalies	9.820
Humus with vegetable remains	14.975
Resinous matter	1.910
	100,000

Ashes of the soil of the heath, before being converted into arable land :—

Silica, with siliceous sand	92.641
Alumina	1.352
Oxides of iron and manganese	2.324
Lime in combination with sulphuric and phosphoric acids	0.929
Magnesia, combined with sulphuric acid . .	0.283
Potash and soda, principally as sulphates and phosphates	0.564
Phosphoric acid, combined with lime. . . .	1.620
Chlorine in common salt	0.037
Sulphuric acid, with potash, soda, and lime .	1.620
	100,000

13. Surface soil of a fine-grained loam from the vicinity of Brunswick. It is remarkable, from the circumstance that not a single year passes in which corn-plants are cultivated upon it without the stem of the plants being attacked by rust. Even the grain is covered with a yellow rust, and is much shrunk. 100 parts of the soil contain—

Silica and fine siliceous sand	87,859
Alumina	2.652

Peroxide of iron, with a large proportion of protoxide	5.132
Protoxide and peroxide of manganese . . .	0.840
Lime, principally combined with silica . .	1.459
Magnesia ditto . . .	0.280
Potash and soda ditto . . .	0.090
Phosphoric acid, in combination with iron . .	0.068
Sulphuric acid, in combination with lime . .	0.068
Chlorine, in common salt.	0.006
Humus	1.109
	100,000

This soil does not suffer from want of drainage: it is well exposed to the sun, is in an elevated situation, and in a good state of cultivation. In order to ascertain whether the rust was due to the constituents of the soil (phosphate of iron), or to certain fortuitous circumstances unconnected with their operation, a portion of the soil was removed to another locality, and made into an artificial soil of fifteen inches deep. Upon this barley and wheat were sown; but it was found, as in the former case, that the plants were attacked by rust, whilst barley growing on the land surrounding this soil was not at all affected by the rust.

14. Subsoil of a loamy soil in the vicinity of Brunswick. It is remarkable, from the circumstance that sainfoin cannot be cultivated upon it more than two or three years in succession. The portion analyzed was taken from a depth of five feet. 100 parts contained—

Silica, with very fine siliceous sand . . .	90.035
Alumina	1,976
Peroxide of iron	4.700
Protoxide of iron	1.115
Protoxide and peroxide of manganese. .	0.240

Lime	0.022
Magnesia	0.115
Potash and soda	0.300
Phosphoric acid, combined with iron	0.098
Sulphuric acid, the greatest part in combination with protoxide of iron	1.399
Chlorine	a trace
	100,000

Now the results of the analysis give a sufficient account of the failure of the sainfoin. The soil contains above one part of sulphate of the protoxide of iron (*green vitriol* of commerce,) a salt which exerts a poisonous effect upon plants. Lime is not present in sufficient quantity to decompose the salt. Hence it is that sainfoin will not thrive upon this soil, nor, indeed, lucerne, nor any other of the plants with deep roots. The evil cannot be obviated by any method sufficiently economical for the farmer, because the soil cannot be mixed with lime at a depth of five or six feet. For many years experiments have been made in vain, in order to adapt the soil for sainfoin and lucerne, and much expense incurred which could all have been saved had the soil been analyzed. This example affords a convincing proof of the importance of chemical knowledge to an agriculturist.

15. Surface soil of a sandy loam in the vicinity of Brunswick, celebrated for its beautiful crops of clover, rye, potatoes and barley. The clover must, however, always be manured with gypsum. The subsoil was taken at a depth of one foot and a-half from the surface. 100 parts contain—

		SUB.
Silica, with coarse siliceous sand	94.274	95.146
Alumina	1.560	1.416

Peroxide of iron, with a little phosphoric acid	2.496	2.528
Peroxide of manganese	0.240	0.320
Lime	0.400	0.297
Magnesia	0.230	0.221
Potash and soda	0.102	0.060
Sulphuric acid	0.039	0.012
Chlorine	0.005	a trace
Humus, soluble in alkaline carbonates	0.444	
Humus	0.210	
	100.000	100.000

The best property of this soil is, that its inferior layers are nearly of the same composition as the superior, as far as the inorganic constituents are concerned. It is a soil upon which the plants mentioned above will seldom fail; and as it possesses a very good mixture to the depth of four or five feet, it would doubtless produce lucerne also.

16. A sandy loam in the vicinity of Brunswick. It produces excellent crops of oats and clover, when the latter is manured with gypsum. Analysis of the subsoil, taken from a depth of one foot and a half from the surface.

		SUB.
Silica and siliceous sand	94.430	89.660
Alumina	1.474	0.980
Peroxide of iron, with a little phosphoric acid	2.370	7.606
Peroxide of manganese	a trace	a trace
Lime, principally combined with silica	0.680	0.954
Magnesia ditto	0.290	0.520
Potash	0.190	0.150
Soda	0.010	
Sulphuric acid	a trace	a trace
Chlorine	0.015	a trace
Humus	0.541	0.120
	100.000	100.000

Both the surface and the subsoil contain or traces of sulphuric acid; hence the application gypsum is attended with great benefit. Withc doubt marl and lime would be found of essent service.

17. Soil from the environs of Brunswick, cc sisting principally of sand, and eminently remark for its sterility. It was, however, much improv by manuring it with marl which contained 24 p cent. of lime, together with magnesia, mangane potash, soda, gypsum, and common salt. 100 pa of the soil contained—

Silica and siliceous sand	95.841
Alumina	0.600
Protoxide and peroxide of iron	1.800
Peroxide of manganese	a trace
Lime, in combination with silica	0.038
Magnesia ditto	0.006
Potash	0.002
Soda	0.003
Phosphoric acid, combined with iron	0.198
Sulphuric acid	0.002
Chlorine	0.006
Humus	1.504
	100.000

Here another proof is presented that a soil m be very rich in humus, and yet be very poor in po of fertility. By means of the marl the inorga ingredients of the plants are furnished to the s which contains them in very small quantities.

18. The soil of a very fertile loam from t vicinity of Walkenried. 100 parts contain—

Silica, with coarse-grained siliceous sand	83.456
Alumina	0.630
Peroxide and protoxide of iron, accompanied with much magnetic iron sand	5.608

Peroxide of manganese	0.560
Carbonate of lime	1.063
Carbonate of magnesia	1.688
Potash combined with silica	0.040
Soda ditto	0.012
Phosphate of lime	0.035
Sulphate of lime	a trace
Common salt	0.005
Humus soluble in alkalies	0.550
Humus, with several azotized organic remains	1.333
	100.000

Gypsum acts most excellently upon this land. The soils in the southern range of the Harz Mountains are particularly remarkable for containing more magnesia than lime. Even the different varieties of marl contain a considerable quantity of magnesia. Thus in a specimen of marl obtained from the vicinity of Walkenried, I obtained 55½ per cent. carbonate of lime, and 30½ per cent. carbonate of magnesia; in another, 41 per cent. of lime, and 11 per cent. of magnesia; and in a third, 47½ per cent. of lime, and 13 per cent. of magnesia. Most of these soils contain also from ½ to 1 per cent. of gypsum, and ½ to 1 per cent. of phosphate of lime, and are therefore well fitted for manuring other lands.

19. Subsoil of a loam from a depth of one foot and a-half; it occurs in the vicinity of Brunswick. The surface soil is remarkable on account of producing beautiful red clover on being manured with gypsum, although the soil itself contains only traces of lime, magnesia, potash, and phosphoric acid. 100 parts of the subsoil contained—

Silica and coarse siliceous sand	88.980
Alumina	2.240
Protoxide and peroxide of iron	3.840
Peroxide of manganese	a trace
Carbonate of lime	2.720
Carbonate of magnesia	0.600
Potash and soda	0.095
Phosphate of lime	1.510
Sulphate of lime	a trace
Common salt	0.015
	100.000

At a greater depth than the subsoil of which the analysis is here given, the soil passes into marl, which contains 20½ per cent. of carbonate of lime. The sulphuric acid deficient in the soil was supplied by means of gypsum.

20. (A) Analysis of a barren heath soil; (B) a sandy soil, containing humus, but also sterile; (C) a sandy soil, possessing the same characters as B. 100 parts contained—

	(A.)	(B.)	(C.)
Silica and coarse siliceous sand	95.778	85.973	96.721
Alumina	0,320	0.320	0.370
Protoxide and peroxide of iron	0.400	0.440	0.480
Peroxide of manganese	a trace	a trace	a trace
Lime	0.286	0.160	0.005
Magnesia	0.060	0.240	0.080
Soda	0.036	0.012	0.036
Potash	a trace	a trace	a trace
Phosphoric acid	a trace	a trace	a trace
Sulphuric acid	a trace	a trace	a trace
Chlorine, in common salt	0.052	0.019	0.058
Humus	0.768	4.636	0.800
Vegetable remains	2.300	8.200	1.450
	100.000	100.000	100.000

21. Analysis of the clayey subsoil of a moor, which, after being burned, is used as a manure to the above soils, A B C. 100 parts contain—

Silica and siliceous sand	87.219
Alumina	4.200
Peroxide of iron, with a little phosphoric acid	5.200
Peroxide of manganese	0.310
Lime	0.320
Magnesia	0.380
Potash, principally combined with silica	0.130
Soda, principally combined with silica	0.274
Sulphuric acid, combined with lime, magnesia and potash	0.965
Chlorine	0.002
Humus	1.000
	100.000

By comparing this analysis with that of the three soils which have preceded, it will be observed that this subsoil is fitted to impart to them those mineral ingredients in which they are deficient.

22. Surface soil of a barren heath in the vicinity of Walsrode, in Luneberg. 100 parts by weight contain—

Silica and siliceous sand	92.216
Alumina	0.266
Peroxide of iron	0.942
Protoxide of iron	0.394
Peroxide of manganese	a trace
Lime, in combination with silica, sulphuric acid and humus	1.653
Magnesia, in combination with silica	0.036
Potash, principally in combination with silica	0.036
Soda	a trace
Phosphoric acid	a trace
Sulphuric acid	0.051
Chlorine	a trace
Humus, soluble in alkaline carbonates	2.084
Humus	1.900
Resinous matter	0.420
	100.000

This soil contains a large quantity of protoxide of iron, which, together with a deficiency of phosphoric acid, is the cause of its sterility. But when the land was manured with the ashes of peat, it was rendered much more fertile. The ashes used for this purpose were found to contain in 100 parts—

Silica, with siliceous sand	96.352
Alumina	1.859
Peroxide and protoxide of iron, with a little phosphoric acid	1.120
Peroxide of manganese	0.160
Lime	0.112
Magnesia	0.141
Potash	0.093
Soda	0.007
Sulphuric acid	0.152
Chlorine	0.004
	100.000

The ashes, on exposure to the air, absorbed ammonia.

23. Analysis of a very fertile soil from Göttingen. It is very rich in humus, and produces beautiful crops of peas, beans, lucerne and beet. The sieve separates from 100 parts of the soil—

Small stones, principally limestone	1
Quartzy sand, with a little magnetic iron sand	15
Earthy part	84
	100

100 parts of the earth, freed from stones, consists of—

Silica and fine siliceous sand . . .	83.298
Alumina, combined with silica . .	1.413
Alumina, partly in combination with humus	3.715
Peroxide and protoxide of iron, in combination with silica	0.724

Peroxide and protoxide of iron, partly free, and partly in combination with humus	2.244
Peroxide and protoxide of manganese	0.280
Lime, with coal of humus, sulphur and phosphoric acid	1.814
Magnesia, combined with silica . .	0.422
Magnesia, combined with humus . .	0.400
Potash	0.003
Soda	0.001
Phosphoric acid	0.166
Sulphuric acid	0.069
Chlorine	0.002
Carbonic acid, in carbonate of lime .	0.440
Humus, soluble in alkalies	0.789
Humus, with a little water	3.250
Nitrogenous matter	0.960
Resinous matter	a trace
	100.000

The subsoil is of the same composition as the surface, with this difference only—that it contains more potash, soda and chlorine, and is interspersed with fragments of fresh-water shells. Hence it is that the soil produces deep-rooted plants in such luxuriance. The portion of the surface soil subjected to analysis, was taken from the field after long-continued rain. Hence the small quantity of salts of potash and soda.

Many more analyses of soils might be given, the result of the researches of Sprengel, who has devoted many years to the investigation of the composition of soils, with the view of proving the importance of the mineral constituents of soils to the plants which grow upon them—a subject deserving the deepest attention of the practical farmer, as it affords the true explanation of the great diversity in the productive power of different soils, from the most sterile, to the most fertile. A careful

examination and comparison of the preceding analyses, and of the observations of Sprengel attached to each, cannot fail to be very interesting and instructive, and especially when considered with reference to the analysis of plants, which will be found in another chapter: as a consideration of both will render most evident the cause of the failure or abundance of crops growing upon different soils. By attention to these analyses, and the annexed observations, it will be evident that plants derive from the soil the mineral substances found in their ashes, and that without their presence in the soil, they could not be produced. If by perpetual cropping, these mineral substances be gradually exhausted, and no fresh supplies be artificially afforded in the shape of manure, the soil will eventually become entirely unproductive. It will appear that a soil may have a great quantity of decaying vegetable matter (humus), and yet be unproductive from a deficiency of the requisite mineral substances; and, on the other hand, that a soil may possess all the latter substances in abundance, and yet be rendered unproductive by the presence of certain matters that are poisonous to plants: such as sulphate of iron, and protoxide of iron, the pernicious effect of which can only be corrected by the application of lime in the first case, and long exposure to the action of air in the latter.

Water, carbonic acid and ammonia which contain the organic elements of plants, and form the great bulk of their substance, though present in the greatest abundance, are quite incapable of supporting healthy vegetation. A seed placed in a medium which is totally devoid of other mineral

substances than mere sand, though fully supplied with the above organic matters, will produce the first organs of growth, roots and leaves, but ceases to increase as soon as the mineral elements which the seed itself contained are exhausted. A feeble stalk, and even a flower, may be produced in some instances, but no seed, as those materials are wanting without which neither the stalk nor leaves can be fully developed, nor the seed produced. Phosphate of lime and magnesia is found in all the seeds of plants, and unless it exists in the soil, the flower, if it be developed, is incapable of forming seed. The same reasoning applies to all the other inorganic substances found in the roots, stalks, and leaves of plants. As so many mineral substances enter into the composition of all plants, and as some require more of a particular kind than of another, it must cease to be surprising that some soils are incapable of producing plants of any kind, and are altogether barren, and that others refuse to support particular classes; on the contrary, it ought to excite our admiration that the mineral substances required by plants are so providentially distributed through a great variety of different soils, and that all the materials are so abundant in many, as to render them highly fertile, and capable of supplying the demands of almost every plant of the particular climate in which they are situated.

There cannot be a doubt, however, that the mineral composition of soils has great influence in determining the natural distribution of plants, and is the cause of particular plants prevailing more than others in certain localities. This natural distribution is most remarkable in the larger kind of

plants—forest trees. Firs require much less of the alkalies and alkaline earths than deciduous trees; they are therefore chiefly found in mountainous situations and sandy soils, which contain these substances only in a very scanty proportion; while the oak, elm, ash, lime, and other deciduous trees prevail upon deep clays and loamy soils, which yield a larger supply of potash, soda, and lime. It is a remarkable fact, however, that in many cases firs prepare the soil for the support of other trees, and of plants which would not previously thrive upon it; and this is effected by the alkalies which, through a long period of time, their roots attract from the depths of the soil, and which are alternately, by the annual fall of leaves and the decay of the branches, deposited upon the surface, and thus render the soil capable of supporting a variety of other plants. When extensive forests of pines in America are destroyed by fire, as is frequently the case, several kinds of deciduous trees spring up and flourish in their place.

The ashes of vines, peas, and clover, contain a large quantity of lime, and accordingly they do not flourish in soils destitute of lime; but by applying lime to such soils, they are rendered capable of supporting these plants. Certain plants grow only on the sea-shore, where they can have a large supply of soda, which they extract from sea salt, and it abounds in their ashes when burnt; others, such as fumatory and wormwood, take up so large a quantity of potash as to render the soil upon which they have grown incapable of producing wheat for a long time after. Clay soils, by their slow further disintegration, afford a lasting supply of potash. By severe cropping with corn, however,

they are for a time exhausted, and require the intervention of fallow and green crops, till a further supply is produced by exposure to the air and the action of lime. Peat soils afford abundance of organic matter for the nourishment of plants, but are so defective in the mineral food of plants, that they are for the most part incapable of bearing corn crops until their surface is burnt, and they receive a dressing of clay, marl, or lime, by which these substances are supplied, and the mechanical condition of the soil at the same time improved.

The salts contained in sea water are, to a certain extent, carried up by the ascending vapour, and are by this means conveyed by strong winds far inland, as has been proved in many instances during the prevalence of storms. In this way a considerable quantity of these salts must be annually conveyed to the soil, thereby contributing to their fertility, and in some cases enabling certain soils in the vicinity of the sea, to support plants, of which they would otherwise be incapable.

The following analysis of sea water by Marcet, with the observations beneath, will show that it contains all the mineral substances that plants require. 1,000 parts of sea water contain—

Chloride of sodium, (common salt)	26.660
Sulphate of soda	4.660
Chloride of potassium	1.232
Chloride of magnesium	5.152
Sulphate of lime	1.500
	39.204

In addition to these constituents, sea water also contains very small quantities of carbonate of lime, magnesia, iron, phosphate of lime, with some

organic matter, ammonia, and carbonic acid. Thus the sea may be considered as an immense magazine of all the elements, both organic and inorganic, which serve as the food of plants, and through them, of animals. The vast forests of sea-weed, which on many coasts occupy hundreds of square miles, and which prevail in all the warm and temperate climates, derive all their nourishment from the water, and provide food for countless numbers of minute animals, which again serve as food for the larger inhabitants of the ocean.

CHAPTER V.

THE NATURE, CONSTITUTION, AND USES OF THE ATMOSPHERE IN VEGETATION.

If we have considered the soil as the habitation of plants, and the source of their *inorganic* or mineral food, we may regard the atmosphere as the medium in which they live and have their being, the investing mantle, which serves both as the magazine and vehicle of those *organic* elements which form the bulk of their substance, as well as the chemical agent by which all their nourishment is prepared for their reception. Considering, therefore, the important part which the atmosphere plays in the process of vegetation, it is well deserving of the attention of the rational farmer, who seeks for an explanation of the phenomena of the growth of plants, in which he is so deeply interested, and who desires to understand the nature of the agencies by which it is effected.

The atmosphere consists of a mixture of elastic fluids, covering the face of the earth, and confined to it by the force of gravitation. Its weight was first determined by Galileo, and afterwards applied by another Italian philosopher to explain the ascent of water in pumps, and that of mercury in the barometer. At the level of the sea it is equal to the weight of a column of water of thirty-four feet in height, and to one of mercury of thirty inches, and presses with the force of 15 lbs. upon every square inch of surface. By the

ascent of mountains, or by means of balloons, this pressure is found to decrease in a geometrical ratio for each equal portion of elevation. At the height of three miles the weight of the atmosphere is diminished one-half, or equal to only fifteen inches of mercury; at double that height the barometer would stand at one-fourth of its former elevation, or at seven and a-half inches; at nine miles it would sink to three inches and three quarters; and at fifteen miles, to little more than one inch. According to the observations of the refraction of light, the utmost height of the atmosphere cannot exceed forty-five miles where it must be exceedingly rare. Independent of the rotation of the earth, which carries the atmosphere with it, the latter is in constant motion, produced by the action of the sun upon the earth's surface, which rarifies the air and causes it to ascend. Under the equator, where it becomes much heated, the ascending currents flow over both to the north and the south, while an under current of cold and heavier air flows back towards the equator, thus causing a constant circulation, which mitigates the intense heat of one region and the coldness of the other. To this cause of the greater and more prevailing motion of the air is to be added the effect of the sun's rays upon the earth in higher latitudes, where the distribution of land and sea produces a diversity of minor currents, called the variable winds. These opposite and conflicting motions, though sometimes destructive, are productive also of the greatest benefit by blending the different constituents of the atmosphere, and preventing the accumulation of noxious vapours, which would prove injurious to animal life, or that

partial distribution which would be unfavourable to vegetation.

We have mentioned the pressure of a column of air of the height of the atmosphere as compared with a column of water and of mercury, by which it appeared that it was equal to thirty-four feet of the former and thirty inches of the latter; the weight of a given volume of air is, however, a separate consideration, and this weight will be affected by the state of the temperature and the height of the barometer at the time, both of which are affected by the weather. When the temperature is 60° Fah., and the barometer stands at 30°, one hundred cubic inches of air weighs about thirty-one grains, so that about 10¾ cubic feet will be equal to 1 lb. avoirdupois.

The atmosphere consists of two principal gases, nitrogen and oxygen, in the proportion of seventy-nine volumes of the former, and twenty-one volumes of the latter, with a varying quantity of aqueous vapour according to temperature, and a small but constant portion of carbonic acid gas. At a mean temperature and pressure, its constitution may thus be stated:—

Nitrogen gas	75.5 by measure	75.55 by weight.
Oxygen gas	21 „	23.32 „
Aqueous vapour	1.42 „	1.03 „
Carbonic acid	0.08 „	0.10 „

Besides these ingredients, the atmosphere also contains always a small portion of ammonia, and in places near the sea, muriatic acid. Other gaseous matters are often contained in the atmosphere: such as the miasms of marshes, the products of volcanos, and putrid exhalations, which affect its wholesomeness in particular situations,

but they are too minute to be detected. Th quantity of aqueous vapour varies exceedingl with the temperature and locality; but the pro portions of nitrogen, oxygen, and carbonic aci gas, are nearly constant at all temperatures and i all situations, from the deepest valleys or the leve of the sea, to the tops of the loftiest mountains as the air examined in France, Spain, the coast c Guinea, and in Egypt, and that brought from a elevation of 22,000 feet, all gave similar result These gases are not chemically united, but merel mixed, and may be considered as distinct atmo spheres of each blended together. Small differ ences in the proportion of carbonic acid ma possibly exist, in certain localities where it abundantly produced, but they are generally s minute as to escape detection, and the constan motion of the air prevents any noticeable exces and soon restores the balance. The nitrogen, o as it is sometimes called, azote, is a perfectl neutral and indifferent gas, and seems to serve n other purpose than to swell the general volume the air, and to dilute the oxygen, which otherwis would be too energetic in its action. It does n appear in the ordinary processes of nature t enter into combination with any of the oth elements, and it is emitted unchanged from th lungs of animals in the act of respiration, an from the leaves of trees; nor can it be made t combine with other elements by artificial mean According to the highest chemical authority, th nitrogen of animal and vegetable substanc originally existed in the form of ammonia, and derived from it.*

* Liebig.

Oxygen is the most efficient part of the atmosphere, and is equally required for the support of both animal and vegetable life, as without it the seeds of plants cannot germinate, and animals instantly die when entirely deprived of it, and rapidly pine away when they are partially supplied with it. In order to prove that the life-supporting power of the atmosphere depends upon the oxygen it contains, numerous experiments have been made which have removed all doubt on the subject. A common experiment is to confine a mouse in a glass jar perfectly closed, when the animal soon dies from the exhaustion of the oxygen. On examining the air in the jar, it is found that the larger part of the oxygen has disappeared, and been replaced by carbonic acid gas and water, which have been produced by the union of oxygen with the carbon and hydrogen in the blood of the animal in the act of breathing, and the quantity of oxygen remaining is insufficient to support life; that is, to duly oxidize the blood, while the carbonic acid acts as a poison. A lighted taper similarly confined in a close jar soon goes out, and from the same cause which deprived the animal of life; namely, the exhaustion of the oxygen by its union with the carbon and hydrogen of the taper. Both these experiments are instances of combustion, only in the latter case the change is more rapid, and is accompanied with the production of light, while in the former the heat is gradually diffused through the body of the animal to keep up the required temperature. These views of the dependence of the life of animals and of ordinary combustion upon the presence of oxygen in the atmosphere, are confirmed by a beautiful experi-

ment of an opposite character. If the jar in which the mouse has died, or the taper extinguished, be inverted over water, and the cover removed so as to shut off any communication with the external air, and then a growing plant be introduced, it will be found that in the course of a few hours the air has regained its former condition, and is again capable of supporting life and combustion for the same length of time as in the first experiment, a convincing proof of the intimate connexion of the life of plants and animals with each other, and of their opposite action in preserving the balance of the ingredients of the atmosphere. In the last experiment the leaves of the plant imbibed and decomposed the carbonic acid gas, retained the carbon, and restored the oxygen. The same reciprocal operations are constantly going on upon the great scale of nature, by which the due proportions are preserved in the vast mass of the atmosphere between its oxygen and carbonic acid gas, for the preservation of the life of animals on the one hand, and the support and growth of vegetables on the other. This arrangement exhibits one of the most important and beautiful instances of the harmony which prevails in the works of creation, and is one of the many that the science of chemistry has revealed to the admiration of mankind of the profound wisdom and beneficence of the Creator, which is increased when we consider the consequences that would result from the absence of such an arrangement as that which actually exists in the elementary constitution of the atmosphere. If the atmosphere consisted of oxygen only, all animals would waste away as in a rapid consumption, as the vital parts

cannot resist the energetic action of undiluted oxygen; and even if it were in much greater proportion to the azote than it actually is, the duration of animal life would be very much shortened, and all other organic forms would be rapidly destroyed by decay and the increased liability to and violence of combustion. If, on the other hand, the normal quantity of oxygen were continually diminished by combustion, the breathing of animals, and decay, and replaced by carbonic acid gas, the atmosphere would ultimately become unwholesome and unfit for respiration, and therefore incapable of sustaining animal life. The latter consequence is prevented by the beautiful economy of vegetation, by which plants are nourished by that gas which is injurious to animals, and the healthful proportions of the atmosphere are preserved by the separation or abstraction of carbon and the release of oxygen.

It has been stated that atmospheric air contains a small quantity of ammonia to the amount, as stated by a chemist of the highest authority, of about 100,000th part of the whole. This arises from the continual decay and putrefaction of vegetable and animal substances, and partly from volcanic eruptions. The existence of ammonia in the air has been proved by the most decisive experiments, and it is the true source of all the nitrogen found in both animal and vegetable substances. It is brought down to the earth by every shower of rain and every fall of snow, and is also imbibed from the air, in the same manner as carbonic acid, by the leaves of plants. As water is composed of oxygen and hydrogen, and the rain brings down both carbonic acid and ammonia, we have in

these all the organic elements both of fat and flesh. The scriptural phrase, that "the clouds drop fatness," is almost literally confirmed by the modern discoveries of chemistry. We have not yet done with the uses of the atmosphere in the processes of vegetation. The pressure of the air is the principal cause of the ascent of the sap in trees, as shown by the experiments of Hales, and further explained by Baron Liebig. The evaporation of water from the twigs and leaves of the plant, together with the expansion of the sap vessels by increased temperature, cause a partial vacuum in the conducting tubes, through which the sap is forced by the pressure of the atmosphere, as in the case of the immersed end of the syphon when the water escapes from the other extremity. The pressure of the atmosphere in causing the ascent of the sap in plants is aided by capillary attraction. The evaporation of water from plants depends much upon the state of the atmosphere with regard to moisture. In very dry and warm weather, when the leaves are fully developed, the evaporation is the greatest; but when the air is moist, and in cloudy weather, it is much diminished, and nearly ceases during rain; and the ascent of the sap corresponds with these conditions, being greatest in the first instance, and least in the last. It appears, therefore, that the state of the atmosphere with regard to temperature and weight, or mechanical pressure, are joint agents in causing the ascent of sap in plants.

The pressure of the atmosphere causes it to penetrate the soil to a considerable depth where it is always actively engaged in effecting the decomposition both of vegetable and mineral sub-

stances. The oxygen of the air decomposes vegetable matter, and produces carbonic acid, which, united with water, effects the decomposition of those substances which afford the mineral food of plants; processes which are always more or less active, in proportion to the state of openness and permeability of the soil and the temperature of the atmosphere.

CHAPTER VI.

THE ORGANIC STRUCTURE AND FUNCTIONS OF PLANTS, WITH ... OF THEIR MINERAL CONSTITUENTS.

PLANTS are organized forms, which deriv subsistence and the materials of their increa the soil by means of their roots, and fr atmosphere by means of their leaves, an green parts above ground. A perfect pla be viewed as consisting of four principal par having its distinct office in the work of n and growth, viz. the roots, the stem and br the leaves, and the bark. The entire body plant consists of cells and tubes, or tube-like destined for the reception and transmission sap. The roots divide into numerous branc fibres, destined to absorb the water of th this they are capable of doing by means c over every part of their surface, but mor cularly by means of their fibres, the extrem which are exceedingly spongy and absorbe are by botanists called spongioles. The st branches are a continuation of the same sy cells and tubes, as those of which the rc formed, and by which the sap is conveyed leaves at their extremities. The leaves co similar tubes, branching into net-like form are everywhere surrounded by other vess green pulpy consistence, and covered by transparent cuticle or skin which is ex

porous, but chiefly on the under side. The office of the leaves is to prepare the crude sap received into them, and fit it for the nourishment and increase of the plant. The bark consists of a somewhat similar arrangement of tubes to that of the wood by which the elaborated juices called the true sap are conveyed from the leaves back to the branches, trunk, and roots, by which their volume is enlarged, or, in other words, by which the growth of the plant or tree is effected. The roots extend themselves in all directions beneath the soil in search of the food they require, and chiefly by means of their extremities imbibe water containing mineral substances in solution; by means of the trunk and branches, but chiefly through their external layers called alburnum or sap-wood, this crude sap is transmitted to the leaves, in the cells of which it is destined to undergo a great change. In addition to the crude sap thus received by the leaves, they imbibe, by means of their pores, carbonic acid and ammonia from the atmosphere; these blended materials, by exposure to the action of light in the organs of the leaves, undergo an elaboration, by which carbonic acid and water are decomposed, oxygen and superfluous water pass into the air, and true sap is formed, which descends through the vessels of the bark, to form a new layer both of wood and bark, and thus increases the general mass. If the leaves of a plant be injured by blight or by insects, its growth will be checked; if they be taken off, it either dies or makes no progress until fresh leaves, the organs of growth, are put forth. Light is indispensable to the healthy action of the functions of leaves, for during the night they cease to absorb and de-

compose carbonic acid; but, on the contrary, they absorb oxygen, and give out carbonic acid, and so far injure the air instead of purifying it. This contrary action is thus accounted for. The carbonic acid, which the plant, by means of its roots, obtains from the soil, as well as part of that which the leaves had absorbed from the air, being no longer decomposed by the action of light, is exhaled unchanged. This change in the action of plants during the absence of light, accounts for the unwholesome effect produced by them in confined apartments during the night. The necessity of the presence of light to the healthy growth of plants, is manifested by them in a manner that bears the appearance of instinct. In large plants and trees the branches diverge, and the leaves expand themselves so as to receive as much light as possible, and in many cases, turning as much as may be with the course of the sun; with the approach of night, the stalks droop, the leaves contract, and the blossoms close. This tendency of plants to seek the light is still more remarkable, when they are placed in a room which light enters only in one direction; thus situated, the branches and leaves stretch themselves so much towards the light, as to produce the appearance of distortion. It is from the absence of a due degree of light for the healthy discharge of the functions of leaves, that the under and lower branches of trees in thick woods and plantations are seen to die, and each individual plant is consequently retarded in its growth. It is from the same cause that underwood ceases to grow when overtopped by tall trees, and beneath the deep shade of the spruce fir, even every blade of grass disappears.

But though light is so indispensable to the healthy progress of plants towards maturity, at the outset, that is, at the very commencement of their existence from seed, it is not required, and is even injurious. The germ of life in the seed is surrounded by matter (starch and gluten,) capable of forming and supplying the substance of the first roots and leaves. This matter must first, however, undergo a chemical change. By the presence of moisture the seed swells, absorbs oxygen, and gives out carbonic acid; by this action a peculiar substance is formed from the gluten, called diastase, which has the effect of rendering both the starch and gluten soluble, and capable of developing the germ into a plume or leaf, which ascends to the light, and a radicle or root, which descends into the ground. The first stage of this curious process is called sprouting, and both its operation and effect in changing the substance of the grain is well seen in the process of malting, by which the tasteless starch of the barley is converted into the sugar required by the brewer.

Now, in this very commencement in the life of a plant, it may be observed, that there are two very distinct actions; the first purely chemical, by which a very small part of the gluten of the seed is converted into diastase, which by its action turns the starch into sugar; the second, the vital action of the germ, by which the food so prepared is formed into the roots and leaves of the young plant.

The presence of a living germ is by no means necessary to the formation of sugar from starch; for if a mere infusion of malt, or malt wort, be mixed with a solution of starch, and kept at the

temperature of about 100° for some time, the whole of the starch will be converted into sugar; and if one part of bruised malt be mashed with three or four parts of ground raw barley, the same amount of saccharine extract will be obtained, after the mash has stood the proper time, as if all the grain had been malted. Distillers have long been aware of this, and for a great many years past have malted only a small part of their barley to produce their wash; but the same economy is denied by the Excise laws to the public brewer, who is compelled to obtain his extract entirely from malt, though it may be practised by the private brewer with great advantage.

The formation of the first roots and leaves of a plant entirely exhausts the nourishing substance contained in the seed; but it is now provided with the means of extracting its future support from the soil and the atmosphere. By an organism as perfect as it is admirable, the mineral substances of the soil and the water, and the carbon and ammonia contained in the invisible air, are combined in forms which clothe the earth with various beauty, support all animal existence, and contribute besides in a thousand ways to the welfare and happiness of mankind.

Many plants, during the earlier stages of their growth, contain a great quantity of sugar in their juices, which is very remarkable in the grasses, and particularly in the cane, which yields the sugar of commerce. Sugar is also obtained from the birch, the maple, and some other forest trees, by tapping them in the spring, and receiving the sap into vessels, which is afterwards clarified, and then crystallized, by evaporation. This is prac-

tised by the inhabitants of the backwoods of Canada, and the United States, who procure by such means all the sugar they require for their domestic consumption. Chaptal, a French author, says, "that, in Germany, Holland, and some parts of Russia, as soon as the returning warmth of the spring begins to cause the ascent of the sap, holes, two or three inches deep, are bored with a gimlet in the trunks of the birch-trees; through the straws which are inserted in the gimlet-holes, there flows out a clear sweet juice, which, after having been fermented a few days, becomes a sprightly liquor, which is drunk by the inhabitants of those countries with much pleasure." The production of sugar is, however, confined to the lower part of the tree, diminishing upwards, and disappears altogether in the extremities. As the season advances, the grasses are found to contain less and less sugar, and it is ultimately not discoverable in them; a change has been effected by the organs of the plant, by which the sugar has been converted into woody fibre—from a sweet and nutritious aliment has been formed a substance which is perfectly devoid of taste, and yields no nourishment to animals. From what is known of the functions of plants, it appears that the formation of woody fibre, of which they principally consist, and other substances contained in their vessels, is not completed in the leaf, but that these substances are the result of subsequent changes of the elaborated sap which take place in the organs of the plant. These changes of the juices of plants are well deserving the attention of the farmer, for, by allowing grass to remain uncut until the seed is formed, the sugar is converted into woody fibre,

to the great injury of the hay, which becomes hard and sticky, and affords very little nourishment, while the gluten of the plant is exhausted in the formation of seed, which, for the most part, is beaten out and lost. This change is most observable in corn crops, which are cultivated for the seed. At the time these plants are in blossom, their stems and leaves are full of juices destined to produce the seed; and if cut when in that state, afford excellent fodder for cattle; but when the blossoms have performed their office in forming the rudiments of the seeds, a large portion of the juices of the plant is yielded up to bring them to perfection. When these are quite full and plump, they are sweet, and consist chiefly of sugar and gluten. In the course of ripening, the former is converted into starch, the seed hardens and arrives at maturity, while the sugar not taken up by the seed is converted into woody fibre in the stem. By thus standing to produce corn, the stems and leaves of plants lose about four-fifths of their nourishing matter, of which they have partly been deprived by the ripened grain. All other grasses intended for hay lose their nourishing properties in proportion to the time they are suffered to stand after the period of blossoming. It is remarkable that starch and woody fibre should be produced from sugar, which they in no way resemble in their external properties. That these changes do take place in the organs of plants is, however, most certain, and are the less surprising when it is known that these three substances differ only in a very slight degree in their component elements. They all consist of carbon and the elements of water, (oxygen and hydrogen); the two latter in

the same proportion which constitutes water, though not combined in that form; for, in the organs of plants, the water is decomposed, and its elements undergo a new arrangement. We are here considering the composition of these substances in their perfectly dry state; that is, when all their moisture is evaporated by a heat somewhat above that of boiling water, and below that at which they become charred. Now, the only difference in the chemical composition of woody fibre, starch, and sugar, consists in the proportion that carbon bears to the elements of water in each of these substances. In 100 parts of each, the proportions of carbon will be nearly as follow:—Woody fibre or lignine 50, starch 44, grape sugar 37; so that the proportion of the elements of water is greatest in the sugar, less in the starch, and least in the woody fibre. By the vital functions of plants these substances are formed from the elements which they are constantly imbibing, and are changed into each other in the progress of their growth, and the maturing of their fruits, either by the addition or separation of the elements of water, or as in the ripening of fruits, by the separation of carbon in the form of carbonic acid. The acids in plants and fruits are produced from the same elements with an excess of oxygen above what is necessary to form water with the hydrogen; and resins and oils result from a diminution of the proportion of oxygen, or as, in some cases, its entire removal. Thus, in the beautiful economy of nature, a great variety of substances possessing properties widely different, are produced from the combination in different proportions of three simple elements which plants derive from the atmosphere.

The ripening of fruits affords a striking instance of the changes which take place in the porportion of these elements. The young apple is woody and almost tasteless; as it advances in growth it consists of starch, and a considerable quantity of acid; in the process of ripening it imbibes oxygen from the air, which, with the excess of oxygen in the acid, is given out as carbonic acid gas, and thus both the starch and the acid are converted into sugar.* This change of the starch and acids of fruits is not limited to the time they remain upon the tree, and therefore is not, strictly speaking, a process of vegetation. It may be more properly considered as a chemical change, which continues after the fruit is removed from the tree. It is well known that grapes become sweeter by being kept after they are gathered; and it is upon the same principle that apples are kept by the most skilful cider makers some weeks before they are carried to the mill, from the experience that they become less acid, and a juice richer in sugar is produced. When apples fall from the tree, they are ripe in the ordinary acceptation of the word, but they are not so in the estimation of those who wish to obtain a rich juice. By keeping the fruit, more of the starch and acid is converted into sugar, and, at the same time, some of the water of the juice is evaporated.

In several kind of trees it has been observed that the alburnum or sap-wood immediately under the bark, contains, in the winter, a large quantity of starch, which has been deposited there during the autumn. This appears to be a store laid up for the development of the buds in the ensuing

* Liebig.

spring. At that season it undergoes a change, being converted by the ascending sap into sugar, which is carried upwards with it, but gradually changes as it ascends, and disappears in the extremities. It is from the lower part of the sugar-yielding trees that the greatest quantity is extracted.

Plants are the laboratories in which all the substances which nourish animals are prepared. Besides starch and sugar, there are other compounds contained in plants and their seeds which are indispensable to animal nutrition, and they consist of the same elements as the former, with the addition of nitrogen, and certain mineral salts. These more compound substances are called vegetable gluten, albumen, and caseine. They contain all the constituents which form blood, and they are strictly identical in all their properties with the fibrine, albumen, and caseine of animal substances. If the flour of wheat be put into a linen bag and placed under a stream of water, and be at the same time kneaded or rubbed in the hand, all the starch of the flour will soon be washed out through the cloth, and there will be left behind an adhesive clammy substance, which, when dried, becomes semi-transparent, and burns like a feather, emitting a similar smell. This is called gluten, or vegetable gluten, and is strictly identical in all its properties with the stringy matter which adheres to a stick when fresh-drawn blood is stirred with it. The quantity of gluten contained in wheat varies very much from 15 to 24 per cent., and in some instances the difference is even greater; that which contains the most, produces the best and most nourishing bread. When the juice of many vegetables, such as cabbages, turnips, carrots,

parsnips, &c. is suffered to stand until the thick matter is deposited, and the clear juice then heated, it becomes turbid, and another deposit takes place, this is called albumen, and is precisely the same in all its chemical properties as the white of an egg, and like it, is soluble in cold water, and thickens with heat. Nuts, almonds, and other oily seeds, consist chiefly of albumen united with oil. Peas, beans, and lentils, when macerated and ground in water, yield a substance of precisely the same properties with the curd of milk; this is called caseine, which is the chemical name of curd. The three last described substances, gluten, albumen, and caseine, though differing in external appearance, are identical in both their organic and mineral compositions; that is, when their parts are separated by analysis, they yield the same organic elements, carbon, oxygen, hydrogen, and nitrogen, in like proportions, and the same mineral substances. The fibrine and albumen of which the blood, flesh, and juices of animals are principally composed, and the caseine or curd of their milk are not produced in the animal system, but are compounded from their elements in the organs of those plants upon which animals subsist; and carnivorous animals derive these substances from the same original source, but through the medium of the herb-eating class which they devour.

The wood, bark, leaves, and fruit of trees and plants yield various substances, which are extensively used in the arts, and in medicine.

Gum, which exudes from an Arabian thorn, and from plum-trees, is composed of the same elements, and in the same proportion as starch and sugar. Fixed oils and resins have nearly the same compo-

sition; but in the latter, hydrogen is in excess, which is the cause of their greater inflammability; while some of the more inflammable of the essential oils are composed of carbon and hydrogen only—such as the oil of turpentine, oil of juniper, oil of lemons, &c. It is needless and inconsistent with our object to enumerate the various vegetable productions used in the art of dyeing, and in medicine.

THE INORGANIC CONSTITUENTS OF PLANTS.

When a plant is burnt, all the organic matter is dissipated, and the ashes which remain consist of various earths and salts, which differ in their nature and proportions in different plants. These substances were originally derived from the soil, and must have been taken up by the roots of the plant in a state of solution in water. The soil, therefore, may be properly considered as not only the habitation of plants, but also the magazine of their mineral food. When the ashes of plants are subjected to analysis by the chemist, they are found to be composed of the following substances, which have been before described; namely, potash, soda, lime, magnesia, silica, alumina, oxide of iron, oxide of manganese, sulphuric, phosphoric acids, and chlorine. Most of these substances, however, exist in the ashes of plants in a state of combination, as salts. Such is the general constitution of the ashes of plants, though all these substances are not found in those of every plant, and frequently vary in their proportions in the same kind of plant

grown in different soils. It may be safely affirmed, however, that the general fertility of soils depends upon the presence of all of them, and that those soils are the most productive in which they all exist in the greatest abundance, all other conditions being equal.

The quantity of inorganic, or mineral matter, differs also very much in different parts of the same plant. It is much more abundant in the leaves of trees than in the twigs and branches, and the latter contain more than the stem or trunk. The leaves of the turnip afford more than twice as much ashes as an equal weight of the bulb, and the straw of the different kinds of grain produces very much more ashes than the same weight of the grain. There can be no doubt but the different requirements of plants as to their mineral food, determines the natural distribution of them in different soils of equal climate; and all the variety observable in the spontaneous productions of land in a state of nature, is chiefly owing to the greater or less abundance of the peculiar mineral food which particular plants require more than others. The same cause which thus influences the distribution of plants, or their aptitude to grow on particular soils in a state of nature, prevails also in those under cultivation, and affords the true reason for the necessity of the rotation of crops, of which we shall have occasion to take more particular notice hereafter. The following analyses by Sprengel, of the ashes of different plants, will show how much difference there exists in the mineral food required by each of those plants most commonly cultivated:—

WHEAT.

100,000 parts of dry wheat contain 1,177 parts of inorganic matter; the same quantity of wheat-straw contains 3,518 parts of earthy matters. These consist of the following substances:—

	GRAIN.	STRAW.
Potash	225	20
Soda	240	29
Lime	96	240
Magnesia	690	32
Alumina	26	90
Silica	400	2,870
Sulphuric acid	50	37
Phosphoric acid	40	170
Chlorine	10	30
	1,777	3,518

BARLEY.

100,000 parts of dry barley contain 2,349, and 100,000 parts of straw 5,242 parts of inorganic matter, consisting of—

	GRAIN.	STRAW.
Potash	278	180
Soda	290	48
Lime	160	554
Magnesia	180	76
Oxide of iron	a trace	14
Oxide of manganese		20
Alumina	25	146
Silica	1,112	3,856
Sulphuric acid	59	118
Phosphoric acid	210	160
Chlorine	19	70
	2,349	5,242

OATS.

100,000 parts of oats in a dry state contain 2,580, and 100,000 parts of straw 5,740 parts of inorganic matter, consisting of—

	GRAIN.	STRAW.
Potash	150	870
Soda	132	2
Lime	86	152
Magnesia	67	22
Alumina	14	6
Oxide of iron	40	2
Oxide of manganese		2
Silica	1,976	4,588
Sulphuric acid	35	79
Phosphoric acid	70	12
Chlorine	10	5
	2,580	5,740

RYE.

100,000 parts of the grain of rye contain 1,04 and 100,000 parts of the straw contain 2,793 par of inorganic matter, consisting of—

	GRAIN.	STRAW.
Potash	532	32
Soda		11
Lime	122	178
Magnesia	44	12
Alumina	24	25
Oxide of iron	42	
Oxide of manganese	34	
Silica	164	2,297
Sulphuric acid	23	170
Phosphoric acid	46	51
Chlorine	9	17
	1,040	2,793

COMMON PEAS.

100,000 parts of seed contain 2,464, ai 100,000 parts of the straw contain 4,179 parts inorganic matter, consisting of—

	SEED.	STRAW.
Potash	810	235
Soda	739	
Lime	58	2,730
Magnesia	136	342
Alumina	20	60
Oxide of iron	10	20
Oxide of manganese		7
Silica	410	996
Sulphuric acid	53	337
Phosphoric acid	190	240
Chlorine	38	4
	2,464	4,971

BEANS.

100,000 parts of seed contain 2,136, and 0,000 parts of the straw contain 3,121 parts of organic matter, consisting of—

	SEED.	STRAW.
Potash	415	1,656
Soda	816	50
Lime	165	624
Magnesia	158	209
Alumina	34	10
Oxide of iron		7
Oxide of manganese		5
Silica	126	220
Sulphuric acid	89	34
Phosphoric acid	292	226
Chlorine	41	80
	2,136	3,121

LUCERNE.

100,000 parts of fresh lucerne contain 2,580 rts of inorganic matter, consisting of—

Potash	362
Soda	166
Lime	1,304
Magnesia	94
Alumina	8
Oxide of iron	8

Oxide of manganese	
Silica	90
Chlorine	86
Sulphuric acid	109
Phosphoric acid	353
	2,580

SAINTFOIN.

100,000 parts of the fresh plant contain 1,6 parts of inorganic matter, consisting of—

Potash	494
Soda	105
Lime	527
Magnesia	69
Alumina	16
Oxide of iron	a trace
Oxide of manganese	
Silica	120
Chlorine	38
Sulphuric acid	82
Phosphoric acid	220
	1,671

WHITE CLOVER.

100,000 parts of white clover in the fresh sta contain 1,735 parts of inorganic matter, consisti of—

Potash	590
Soda	110
Lime	446
Magnesia	58
Alumina	36
Oxide of iron	12
Oxide of manganese	
Silica	280
Chlorine	40
Sulphuric acid	67
Phosphoric acid	96
	1,735

LINSEED.

100,000 parts of linseed contain 2,340 parts of inorganic matter, and 100,000 parts of stem contain 1,456 parts, consisting of—

	SEED.	STALKS.
Potash and soda	438	510
Lime	630	230
Magnesia	234	480
Alumina	2	2
Oxide of iron	a trace	10
Oxide of manganese		
Silica	120	20
Chlorine	12	20
Sulphuric acid	24	66
Phosphoric acid	880	118
	2,340	1,456

BUCKWHEAT.

100,000 parts of the seed of buckwheat contain 1,354 parts of inorganic matter, and 100,000 parts of the dry straw contain 3,203 parts, consisting of—

	SEED.	STRAW.
Potash	204	332
Soda	330	62
Lime	156	704
Magnesia	183	1,292
Alumina	26	26
Oxide of iron	8	15
Oxide of manganese	44	32
Silica	144	140
Chlorine	15	95
Sulphuric acid	74	217
Phosphoric acid	170	288
	1,354	3,203

BEET.

100,000 parts of dry beet-root contain 5,986 parts of inorganic matter, and 100,000 parts of the dry leaves *contain 15,439* parts, consisting of—

	ROOT.	LEAVES.
Potash	1,481	5,600
Soda	3,178	3,290
Lime	285	2,316
Magnesia	139	839
Alumina	20	130
Oxide of iron	58	50
Oxide of manganese	50	60
Silica	105	425
Chlorine	380	1,064
Sulphuric acid	123	975
Phosphoric acid	176	690
	5,986	15,439

PARSNIP.

100,000 parts of dry parsnip roots conta 4,643 parts of inorganic matter, and 100,000 par of the dry leaves contain 15,661 parts, consistin of—

	ROOT.	LEAVES.
Potash	2,310	3,207
Soda	780	2,448
Lime	520	4,160
Magnesia	300	473
Alumina	26	132
Oxide of iron	5	9
Oxide of manganese		
Silica	180	1,400
Chlorine	198	1,950
Sulphuric acid	213	1,198
Phosphoric acid	111	1,784
	4,643	15,661

CARROT.

100,000 parts of dry carrot contain 5,090 par of inorganic matter, and 100,000 parts of the d leaves contain 10,420 parts, consisting of—

	ROOT.	LEAVES.
Potash	2,718	3,236
Soda	907	921
Lime	505	3,050
Magnesia	295	398
Alumina	30	78
Oxide of iron	25	15
Oxide of manganese	46	
Silica	105	454
Chlorine	54	223
Sulphuric acid	208	1,082
Phosphoric acid	395	963
	5,090	10,420

The several alkaline and earthy substances or ses mentioned in these analyses, existed in the ants in a state of combination with the mineral with vegetable acids. The soda, potash, and ne, which appear in the ashes as carbonates, ve served in the plant as the basis of vegetable ids, which have been destroyed by burning, and placed by carbonic acid. Plants possess the wer of decomposing the mineral salts, which ey take up from the soil, and of re-arranging eir elements in new combinations suited to their quirements; though some portion of these salts -appear in their ashes when burnt, in the same rm in which they entered the roots. By a mparison of the constituents of the ashes of ants, it will appear that they consist of very unual quantities of the different kinds; it therere follows, from this inequality, that a crop of e kind will succeed in a soil in which another ould fail, from the want of a due supply of the rticular mineral food required.

The following table of the quantity of potash forded by *some common* trees and plants is given

by Sir H. Davy, and presents a very striking view of great disparity in their requirements:—

10,000 parts of	Oak contained	15	parts of potash.
"	Elm	39	"
"	Beech	12	"
"	Vine	55	"
"	Poplar	7	"
"	Thistle	53	"
"	Fern	62	"
"	Cow thistle	196	"
"	Wormwood	730	"
"	Vetches	275	"
"	Beans	200	"
"	Fumitory	790	"

Plants cannot grow without a due supply of all the substances found in the ashes of each when burnt, and therefore if any of these be entirely absent, the plants cannot be produced; and if the quantity be insufficient, a corresponding effect will ensue, in the diminution of the size and number of plants, and the productiveness of the crop.

CHAPTER VII.

E CONSTITUTION OF ANIMAL SUBSTANCES—EXHAUSTION OF SOILS.

IE flesh and blood of animals consist of the me chemical *elements* as those contained in vegebles from whence they are derived, but with a ach larger proportion of nitrogen and less of ygen, which constitutes the principal difference tween them. The mass of the flesh consists incipally of *fibrine*, with variable quantities of t, albumen, and gelatine (jelly), the two latter ing contained in the juices. In raw fresh meat ese substances are united with 75 per cent. of ter, and the dry matter affords, when burnt, ther more than 4 per cent. of ashes. The fibrine gluten and albumen of animal substances are ecisely the same in chemical composition and operties as that contained in vegetables. The llowing is the analysis of dry ox flesh and dry ood given by Professor Playfair, by which it ill be seen that they are formed of the same oportion of organic elements, and also yield the me quantity of ashes:—

	FLESH.	BLOOD.
Carbon	51.83	51.95
Hydrogen	7.57	7.17
Nitrogen	15.01	15.07
Oxygen	21.37	21.39
Ashes	4.23	4.42

he slight differences observable, fall within the nits of unavoidable error.

Blood is composed of the following compound substances, or proximate principles, according to the analyses of Lecanu, given in "Turner's Chemistry." 1,000 parts contain—

Water	780.145
Fibrine	2.100
Colouring matter	133.000
Albumen	65.090
Crystalline fat	2.430
Oily matter	1.310
Extractive matter	1.790
Albuminate of soda	1.265
Alkaline chlorides, carbonates, phosphates, and sulphates	8.370
Carbonates of lime and magnesia, phosphates of lime, magnesia, and iron, peroxide of iron	2.100
Loss	2.400
	1000.000

When meat is subjected to the action of boiling water for a considerable length of time, the greater part of the albumen, together with the whole of the fat, gelatine, and the flavouring matter containing the salts, are extracted by the water, which accounts for the richness of the soup and the tasteless hardness of the meat when overdone, which consists of little else than fibrine. The tenderness of meat depends upon the quantity of albumen it contains, and this is much less in the flesh of old than in young animals. If meat be chopped small, the whole of the albumen and flavouring matter may be readily extracted by cold water, and afterwards the gelatine and fat by boiling.* When raw meat is acted upon by hot water, in the ordinary process of boiling, it

* Liebig.

loses about 17 per cent. of its weight. Fibrine, when divested of all other substances, is a white, tough, fibrous substance, perfectly tasteless, and insoluble in water; the albumen which forms some of the solids of animals, as well as a portion of the fluids, is the white glary substance of the white of egg, and is soluble in cold water, but coagulates with heat. The gelatine which, though it forms but little more than the fortieth part of dry meat, gives the jelly-like consistence to rich soups when cold, affords less strengthening nourishment than gluten and albumen, as by itself it is incapable of forming blood. The skin, horns, and hoofs of animals consist almost entirely of gelatine; and hair, wool, and feathers are nearly of the same composition. When skin is boiled it produces glue, which is hardened gelatine, and when steeped for a long time in water containing tannic acid, as in the tan-pit, it is converted by union with the acid, into the insoluble substance, leather. The fresh bones of animals consist chiefly of phosphate of lime and magnesia, with a small quantity of carbonate of lime, a large portion of gelatine, about 30 per cent., with some fat. When bones are digested in a strong acid, the earthy matter is dissolved, and the gelatine remains as a flexible, semi-transparent substance, of the exact form of the bone. Teeth are composed of the same, with a larger portion of earthy matter. It has been observed that the bones and flesh of animals contain the same inorganic elements as vegetables, from which they are derived, though some of these elements have undergone new arrangements in the organs of the animals, by which *their combinations* have been changed.

It is a very interesting and beautiful arrangement in the economy of nature, that the same mineral substances which are essential to the production of plants, are equally required to form the juices and solids of the animal part of the creation. By means of the digestive organs all the parts of vegetables which are capable of forming blood, are taken up and distributed; but, as every part of the animal frame is continually undergoing waste and renewal, those substances which are no longer required are again removed by the blood, and are finally discharged from the system as solid and fluid excrements. Lastly, when the animal has lived its appointed time, the elements of which it is composed are returned to the atmosphere and the soil, to re-appear in new forms of vegetable and animal existence.

THE EXHAUSTION OF SOILS.

It has been observed in a former part of this treatise, that soils have been derived from the disintegration of the component parts of rocks. The constant changes of weather from dry to moist, and the action of frost, have a powerful influence in producing division, and water containing carbonic acid is capable of dissolving the alkalies and alkaline earths contained in rocks, the parts of which being thus disunited crumble down and form soils.

This action of the weather, continued through a long lapse of ages upon rocks the most liable to its influence, will progressively increase both the depth and mineral riches of the soil. Plants also *contribute* to this effect by means of the carbonic

acid produced by their decay, and the acids they are known to exude from their roots in a living state, and thus become powerful agents in promoting the disintegration of rocks.

A soil which for centuries has thus accumulated and been acted upon, and from which the alkalies and other substances have not been removed, will afford a large supply of the mineral food of plants, and, when brought into cultivation, will sustain incessant cropping for a great number of years without any apparent abatement of its fertility. It must, however, at length become exhausted, unless artificially supplied by means of manure, or the land be suffered to remain without being sown with exhausting crops for a certain time, till nature has restored, by a further decomposition, those mineral substances, chiefly alkalies, and soluble silicates, which had become deficient.

The first settlers of North America found a virgin soil, from which nothing had been carried away, so fertile, that they thought it inexhaustible; but, by the constant growth of exhausting crops, corn, cotton, tobacco, flax, and hemp, its fertility diminished, and it ultimately became so far impoverished as to be incapable of producing remunerating crops without the aid of manure. On the rich alluvial land in the valley of the Mississippi above New Orleans, cotton is cultivated until it will no longer yield a profitable crop, when it is abandoned, as the planter finds it cheaper and more advantageous to purchase and bring into cultivation new land, than to keep up the fertility of the old by the aid of manure.

In all old-peopled countries which have been under cultivation from the earliest times, the

fertility of the soil can only be maintained by restoring, in part at least, by means of manure, that which had been taken away, and by fallows and fallow crops, which do not exhaust the alkalies and silicates produced by a farther disintegration of the soil. In the country round Naples, where, in many places, there are no homesteads nor roads by which manure can be supplied, the soil formed by the decomposing lava is so rich in the mineral substances required for corn crops, that by mere rest it is rendered capable of producing luxuriant crops of grain, which it has continued to do for many centuries, the intervals affording by disintegration fresh supplies of the mineral food required. No green crops or even fallows intervene. We must conclude from what has been stated above, on the authority of Baron Liebig, that such lavas contain an inexhaustible store of all the mineral substances required for sustaining corn crops.

Such soils as these are happily confined to particular spots, as they are found only in countries often desolated by earthquakes, and the destructive effects of volcanos and streams of molten materials, producing calamities which far overbalance the advantage of any degree of after fertility. The generality of soils soon cease to produce, if the mineral substances carried away from them in the shape of saleable productions be not replaced by the industry of the farmer. Though the total amount of inorganic substances required by plants be very small and apparently insignificant, yet they must all be present in the soil to maintain a successful course of cropping; and as some plants require *more of* some of these than others, the general

exhaustion will be indicated by the failure of one crop after another, as each finds the deficiency of that kind of mineral food which it most requires. The deficiency of any one material will cause a diminution of the crop, as there will not be enough for above a certain number of plants upon a given space of ground, and the total absence of that individual material must cause an entire failure.

In the course of the exhaustion of a soil by successive crops of corn and other produce, the effect will be explained by a careful analysis of the soil, which can only be effected by a skilful chemist, and a comparison of this analysis with those substances contained in the ashes of the plants it is required to produce. One crop will require more potash, a second more common salt, a third more bone-earth, or of carbonate of lime, &c., than the land can supply, to produce a good crop. These deficiencies will cause a continually-diminishing crop of each kind, until the soil ceases to remunerate the expense of ploughing, sowing, and seed.

This is the extreme case of the exhaustion of land, the fertility of which it is often attempted to restore by laying it down with grass, which, however, is a fruitless attempt, as the grass itself requires the same nourishment as the crops which have failed, and will on most soils, for many years, afford only a scanty herbage, unless assisted by heavy dressings of manure.

It often happens that farmers, not being aware of the true cause of the failure of their crops, and that *all* the mineral substances found in the ashes of plants *are essential* to their existence, make

attempts to renew the powers of the land by the application of a single salt. The accidental success of such attempts have led to many severe disappointments, and they can only prove beneficial in cases of partial exhaustion, and when the substance applied happens to be the only one deficient, whether it be common salt, nitrate of soda, nitrate of potash, bone-earth, &c. Though any one of these *may* prove beneficial, it cannot be relied upon, because there is no certainty that it was the particular substance deficient in the soil, and that some others were not equally so. The small quantity of bone earth (phosphate of lime and magnesia) generally contained in soils, and the constant demand upon it in supplying corn crops, and the bones and flesh of cattle, and also of sheep and their wool, frequently causes it to be very deficient, which accounts for the great effect it oftentimes produces when singly applied. The repeated application of bone-earth singly as a means of fertility fails to prove efficacious; above a certain amount, and that a small one is not required; and the failure proves that some other substance or substances have become deficient.

CHAPTER VIII.

THE APPLICATION TO LAND OF LIME, MARL, CHALK, BURNT CLAY, CALCAREOUS SAND, PEAT, AND PEAT ASHES.

Lime is very extensively used throughout all the western and north-western parts of England, and the whole of Scotland, where it is considered indispensable to good farming; but the reason of its efficacy is very imperfectly understood by the generality of farmers. A brief account of the nature of lime has already been given, and we have now to consider its chemical action upon soils.

By burning limestone in a kiln it is deprived of its carbonic acid, and becomes caustic or quick lime. In this state it is capable of exerting a very powerful action on vegetable and animal substances, by its strong affinity or attraction for water and carbonic acid, the elements of which those substances contain. When applied, therefore, to land containing an excess of vegetable matter, as when newly broken up from pasture or common, its first action is to break down, and reduce to a more manageable state, the stubborn sward, and to render the rough fibrous matter capable of affording nourishment to plants by becoming soluble in water. By this process it becomes again *mild lime*, in which state it serves as

a part of the mineral food of plants, and forms a valuable mechanical constituent of the soil.

Caustic lime also acts chemically upon clay soils by uniting with their silica, and liberating potash, which clay always contains. The last mentioned effect of lime is very important, and the recent discovery of it by a German chemist, affords one of the most interesting lights that chemistry has thrown upon the practical operations of agriculture. Lime has the effect of decomposing sulphate of iron, which sometimes exists in soils, and is very injurious to vegetation. By this action it not only destroys a pernicious salt, but at the same time produces sulphate of lime or gypsum, which forms part of the food of plants. Those limestones which contain clay, as the brown lime and hydraulic limestone, (blue lias,) also afford alkalies, and the latter stone is rich in phosphate of lime. According to some recent examinations of several limestone rocks by Dr. Daubeny, all, more or less, were found to contain phosphate of lime, to the presence of which there can be little doubt a considerable part of the benefit of lime is due. Lime has a very beneficial effect, when applied in its caustic state to land, in destroying slugs and the eggs and maggots of insects, which often prove very destructive to crops.

To have all the benefit of the chemical action of lime upon arable soil, it should be spread as soon as slacked before its caustic property is diminished, and ploughed in and well mixed with the soil. Its application is most conveniently effected by depositing it as it comes from the kiln in small heaps, of about 4 bushels each, over the field, and

immediately covering them up with earth, by the moisture of which it will soon be slaked, and spreading it as soon as this has taken place: indeed, great diligence must be used to get it spread before it loses its powdered state. The quantity of lime applied to land per acre varies, in different districts, from 40 to 300 bushels. When used in small quantities, it is repeated in every course of cropping, or once in four or five years, but when the larger quantities are applied, it is done at intervals of many years. In Scotland the latter practice prevails, and it is said to be found by experience to be most beneficial, though the opinions of practical men are much divided upon this point. A consideration of the chemical action of lime would recommend the application of small and repeated doses in preference to larger quantities at long intervals. It is, however, well known that when large quantities of lime are applied, no further effect has been produced, or at least has been observed, by an early repetition. Lime is also highly beneficial to the old pasture land which covers the very rock from which the stone is taken. By the application of a large dressing of lime, a poor and wiry grass is succeeded by an abundant and succulent herbage, chiefly consisting of white clover; and this effect continues for many years, during which no advantage can be gained from a renewed liming. It is highly probable that in this case, as well as in the application of lime to arable land, the more lasting effect is owing to phosphate of lime, and potash. The above surprising effect of lime is experienced upon the Mendip Hills of Somerset, and is well deserving the *attention* of the practical farmer,

and of the investigation of the chemist by a careful analysis of the stone. It should always be remembered that lime, independent of any other substances which limestone may contain, is itself required as a part of the mineral food of plants, as it constitutes a large portion of their ashes, in which it is found as a carbonate, which accounts for one cause of its great benefit to soils which are naturally destitute of it.

From what has been said of the chemical action of quick lime upon vegetable substances and upon clays, its use in forming composts will be easily understood. By its decomposing action upon peat, the scouring of ditches, spent bark, and other inert or rough vegetable matter, they are broken down and rendered capable of undergoing still further decomposition in the soils, and thus yielding their elements for the nourishment of plants. When mixed with clays and marls, its action liberates the alkalies they contain, which come in aid of the fertilizing power of the unchanged portion of the lime when applied to the soil. Lime should never be applied to, or mixed with, farm-yard or stable dung, as it dissipates their ammonia, by which an important agent of fertility is lost. There is a method of treating lime for agriculture, which, near the sea coast or to brine-pits, appears well deserving of attention. It is mentioned by Sir John Sinclair in his "System of Scotch Husbandry" as practised with admirable effect, and is described as follows: "Slake 32 bushels of lime with sea water previously boiled to the state of brine, or the strength of soapers' lees. This quantity is sufficient for an acre of land, and may be either thrown out of the cart with a shovel over

the land, or made into compost with 40 cart loads of peat or earth, in which state it will be found to pay for the additional expense. All the experiments have done well with it, but especially with wheat and beans, and it has not been behind any manure with which it has been compared. There is one instance in which it was tried in comparison with 72 loads of soaper's waste and dung, and although this was an extraordinary dressing, nevertheless, that with lime and brine was fully above the average of the field. It is calculated by Mr. Mitchel, that 3,000 gallons of sea water boiled down to 600 gallons, will slake 64 bushels of lime, or a quantity sufficient for two acres of land; and the total expense of lime, brine, slaking and carting, he makes thirty shillings." In convenient situations, evaporating pans might be formed on the sea shore, which would greatly reduce the expense. There can be no question that the mixing of lime so prepared with peat, would be a great improvement, as by that means the materials of the peat are also brought into action, and a very powerful saline compost must be the result.

The effect of this manure is what might be expected from a consideration of the composition of sea water, which, as before stated, contains all the mineral substances which serve as the food of plants. The benefit of this mode of using lime has been lately confirmed by the experience of the Rev. Mr. Vincent, as given in a letter to the president of the English Agricultural Society, in the following words. "On the sea coast of Caernarvon, in several places about two feet beneath the surface of the land, *and below high*-water mark, there is a decayed

vegetable deposit of turbary, of the thickness of four or five feet, strongly impregnated with salt; of this I have been in the habit for several years of making a compost, such as was recommended by Lord Meadowbank, by mixing it with dung. In a few days after incorporation, a very strong heat is produced, and as soon as the fermentation begins to diminish, I have it carried on the turnip ground, and it has proved invariably as effective as an equal quantity of rotten dung. Last year, having seen an account of lime and salt as a manure, I thought that the saline turbary of mine might be equally effectual. I accordingly caused several cart loads of it to be carried to a shed, and when well pulverized it was thrown into a heap and mixed with a cart load of coal ashes, and during the operation of mixing, about a barrel of soapsuds was thrown into the heap. I then procured a cart load of lime, and having reduced it to powder with water, it was thrown into another part of the shed. The two heaps having remained separate for about a month, they were then well mixed together. In three or four days, the compost became as hot as a dunghill, a strong fermentation having taken place. It was allowed to remain in this state for a few days longer, when, the heat beginning to decrease, it was carried into the field prepared for turnips, and spread with the drills in the same manner as bone dust. The crop proved a very good one, from 30 to 35 tons per acre, and was considerably better than that manured with bone dust the year before, on land of the same quality." If Mr. Vincent had broken the moist *peat and* mixed it with lime, the latter would have *been* slaked in contact with the peat, and a sub-

sequent turning or two would have completely blended them, and produced all the desirable effect at much less expense.

MARL.

Marl consists of silica and alumina (clay), and a variable proportion of carbonate of lime. Upon the examination of several specimens, Chaptal found that the quantity of carbonate of lime varied from 10 to 60 per cent. The presence of carbonate of lime is easily detected by throwing it into muriatic acid diluted with water, when a strong effervescence takes place in proportion to the quantity of carbonate of lime in the specimen; and the exact proportion may be ascertained by drying the marl at a high temperature, and then submitting a certain portion of it, say 500 grains, to the action of the diluted acid, till all effervescence ceases, which indicates that all the lime is dissolved. Now, pour off the liquids and dry the earthy matter at the same temperature as before, when the loss in weight will show the quantity of carbonate of lime which the marl contained. The quantity of acid should be rather in excess, which may be known by tasting the liquor when the effervescence has ceased.

The richer the marl is in carbonate of lime, the more beneficial it generally proves as a dressing for pasture land, and therefore its efficacy has been thought to be entirely owing to that substance. It has, however, been recently discovered that marl contains small quantities of phosphate of lime, sulphate of lime, and some potash; to which, there can be no doubt, some, if not the greater part of its benefit *must be* ascribed.

Marl appears to have been used from the earliest times as a manure for grass land, and it is very remarkable that it produces the most powerful effect upon the land from beneath which it has been dug. We have often seen it spread upon the grass of the field where it was raised at the rate of 40 or 50 loads per acre. The surface, which previously was mossy, and produced but a scanty and inferior herbage, was soon covered with an abundant crop of grass of the best quality. After a heavy dressing, such as that mentioned above, no repetition is needed for many years, nor will it have any effect. The duration of its beneficial effect will of course depend upon the quantity applied, and the period of successful renewal vary accordingly. When marl is applied to grass upon light sandy soils, to which it is most beneficial, it is observed on examination, that it gradually subsides, and at length gets below the reach of the roots. It is probable, however, that during its subsidence, and perhaps before it has so sunk out of reach, it has been exhausted of those substances to which it principally owed its fertilizing effect. The effect of marl is very much increased by burning, in which case it will not in all probability last so long. We have seen a large nursery on the sand of the inferior oolite in Somerset, which was kept in the highest state of fertility by means of burnt marl dug upon the spot, and without any foreign means being applied; a certain proof that the marl must contain other substances than merely clay and carbonate of lime. This marl is burnt in kilns, in which a fire of wood or coal is first kindled, and when a good heat is got up, the marl is gradually thrown on in spits until the kiln is quite full.

This is a very striking instance of fertility produced by the mere application of the mineral food of plants, by the aid of which they are enabled to appropriate the inorganic elements conveyed to them by the atmosphere: the mineral substances in the marl supplied the deficiency of the soil, and their addition completed the conditions of fertility which were before wanting.

BURNT CLAY.

Burnt clay has been frequently recommended as a means of improving land, and in many instances has been used with great success. It must be a great improver of the mechanical condition of heavy clay soils, by rendering them more open to atmospheric influence, and more easily worked; it has also the power of absorbing ammonia from the air, which, being condensed in its pores or interstices, is rendered available to the roots of young plants, before the leaves are sufficiently expanded to derive it directly from the atmosphere. Clays often contain the mineral substances necessary to fertility, which in their natural state are not available to plants, but such clays are rendered eminently fertile by calcination. Baron Liebig mentions that he saw an example of this in the garden of Mr. Baker, at Hardwich, near Gloucester. The soil consisted of a stiff clay, which, from being completely sterile in its natural state, was rendered very fertile by burning. It has been observed, that burnt or quick lime, by its action on clay, liberates potash, and when chalk and clay are burnt together, the same effect is manifested in a striking manner. In *London*, where the bricks are made

with clay mixed with chalk, in damp weather the new walls of a house are often seen covered with a white efflorescence of alkaline salts; these have been produced by the decomposition of the silicates of the clay, which always contains them, the lime uniting with the silica and liberating the alkali. The same effect takes place in the burning of marl, which this compounded brick clay resembles, and it is more than probable that such clays as contain some portion of carbonate of lime produce a greater effect when burnt. In some instances, burnt clay has failed of producing the expected result. If in these cases of alleged failure the land had been previously much exhausted, (which very probably was the case,) it could scarcely be expected that the application of burnt clay alone would be sufficient to render it fertile: it would at least be a very unreasonable expectation.

It is very likely that in these instances of failure the clays contained little or no carbonate of lime, in which case one very important cause of the improvement of the soil would be wanting, namely, the action of lime on the clay. At best, the effect of burnt clay should be considered as an important accessory to fertility, and not as a substitute for other ordinary means to secure that object. The many cases in which burnt clay has proved beneficial would justify an experiment in any locality where stiff clays occur, the result of which might lead to a most important improvement of the capability of the soil.

Clay is burnt with but little fuel, in heaps of from 50 to 100 cart loads each, and at an expense of from 6*d.* to 7*d.* per cubic yard. The quantity used on arable land is 40 to 50 cubic yards, and

25 on pasture. Some very interesting communications on this subject will be found in the Appendix, extracted from the "English Agricultural Journal," in which many particulars are given by Mr. Pusey, the late president of the Agricultural Society, and Mr. Pym, of Baldock, of the mode of burning clay and its successful application.

The extensive strata of clay, which occupy so large a portion of the south and east of England, present an ample field of improvement by this means, from which it seems probable that agriculture is destined to derive more benefit than from any other untried resource. Our present cold and unproductive clays may be considered as magazines of agricultural treasure hitherto locked up, which wait to be opened by the enterprise, skill, and industry of the rising and future generations.

CHALK.

This substance is a great improver of both clay and sandy soils, and the plastic clay which overlies it, and the green sand beneath it, so opposite in character from each other and from the chalk, are precisely the soils to which the latter is calculated to render the greatest benefit both chemically and mechanically. Chalk appears to have been used as an improver of clay soil in very early times, as appears from the many old pits in Wiltshire and Berkshire which have been before alluded to, from whence large quantities have been raised, as appears by the extent of the excavations. The same practice continues to the present day. The mechanical benefit of chalk to stiff clay must evidently be to render it more open, while its chemical

properties are somewhat similar to that of burnt lime. Carbonate of lime, of which chalk is almost entirely composed, possesses the power of effecting the decomposition of clays, which is only rendered more energetic by being burnt as before noticed, and its action in this respect must be the same as that of unburnt marl. Chalk, in all probability, contains nearly the same fertilizing substances as marl, as it is for the most part a deposit from innumerable animalculæ, whose minute shells are rendered visible by the microscope. A considerable quantity of phosphate of lime has been found in the chalk on the coast of France, and most probably exists in ours, and as sulphuret of iron is very common in the chalk, it must contain sulphate of lime, as the nodules of the former substance are frequently found to have been decomposed. It is most certain, that wherever chalk occurs in the near vicinity of clay or sandy soils, it is calculated to be of the greatest benefit by copious applications of it, both by its constitution and its action.

CALCAREOUS SEA SAND.

Along the northern coast of Devon and Cornwall, from Bude Harbour to St. Ives, there are extensive tracts of calcareous sand which the sea washes upon the coast, from whence, where the shores are low, it is blown inland and forms high downs. This sand is a constant source of fertility to the country round, and immense quantities are annually carried to great distances as the best dressing they can apply to their land. It appears to consist chiefly of broken shells and coral, as the calcareous matter forms from 44 to 70 or 80 per *cent. of* the whole. That which is dug in the harbour

of Padstow is considered the most valuable, and is said to contain at least 80 per cent. of carbonate of lime. From that part of the coast a railroad has been constructed to Bodmin, the principal object of which was the conveyance of sand to the interior. The farmers never take the sand that has been drifted by the wind, though it would save them much labour, but go down to the coast and dig it beneath the high-water mark when the tide is out; experience having proved to them that the drifted sand which has been exposed to the action of rain is much less fertilizing than that which is daily under the sea water. This practice affords a clue to a principal cause of its beneficial effect. It cannot be supposed, that frequent dressings of mere calcareous matter can support constant fertility; if it were so, the drift sand would be equally effectual with the other; but in using the fresh dug sand, they obtain with it the salts contained in the sea water, as well as those which have been deposited and not washed out, which, it has been before observed, afford all the mineral elements of plants. There can therefore be no doubt as to the cause of the preference of the fresh sand, before that which has been subject to the action of fresh water and wind. It appears from historical documents that this sand, like marl, has been used from the earliest times, but it was not till within these few years that the cause of its fertilizing effect could be explained. After enumerating all the substances contained in sea water, Baron Liebig observes, that "the same conditions which sustain living beings on the land are combined in this medium, in which a whole world of other plants and animals exist."

PEAT.

Peat consists of the remains of aquatic and other plants which have undergone a partial decay or decomposition, and of which carbon is the principal constituent; the further progress of the work of destruction has been arrested by the loss of most of the other inorganic elements, which has reduced it to a somewhat similar condition to charred wood, which is known to resist the action of decay. Its further decomposition, however, can be effected by artificial means, as will be explained in the sequel.

Peat may be sometimes advantageously used as a dressing to land. Lands which are liable to be burnt up by the heat of summer weather are greatly benefited by peat, which absorbs and retains moisture; and on such soils it has been applied with considerable effect. In these cases it should be used in large quantities, and wherever practicable should be applied with the addition of lime, either separately, or in the form of compost. By the action of lime, peat continues to undergo further decomposition, so that besides improving the absorbent property of the soil, it yields by its decay some of the elements which constitute the food of plants. The benefit of peat to clay soils would arise from it rendering them more open and absorbent of atmospheric moisture in dry weather.

Peat is chiefly used as a manure in the form of ashes, which are extensively applied in the counties of Wiltshire, Berks and Hampshire as a dressing for turnips and clover, but it is only in particular places that it affords valuable ashes for that purpose. Those of Woodbridge and Newbury are of the

best quality, and are conveyed to a great distance. These ashes are, no doubt, rich in the mineral requirements of plants. Of a most valuable peat ash from Luneberg in Germany, Sprengel gives the following analysis. 100 parts contained:—

Silica, with siliceous sand	96.352
Alumina	1.859
Peroxide and protoxide of iron, with a little phosphoric acid	1.120
Peroxide of manganese	0.160
Lime	0.112
Magnesia	0.141
Potash	0.093
Soda	0.007
Sulphuric acid	0.152
Chlorine	0.004
	100.000

The following is an analysis of very valuable peat ashes brought from Holland, where they are greatly prized and very extensively used. 100 parts contained:—

Siliceous earth	32
Sulphate and muriate of soda	6
Sulphate of lime	12
Carbonate of lime	40
Oxide of iron	3
Impurities and loss	7
	100

Sir John Sinclair gives the following account of the mode of the application of these ashes in the Netherlands, the original school of English agriculture:—

" In March the wheat is worked with the hoe between the rows, and the land is sown with clover, and in May the wheat is hand-weeded. The crop being reaped, the land is harrowed in the

following spring, and then the ashes are spread by the hand in calm and hazy weather, at the rate of 18 or 20 bushels per acre. They are also laid on pasture and on wheat in March and April, on oats and beans in the beginning of May, and rye in October and November. Their chief employment is, however, on green crops; it having been found on comparative trials in Flanders, that when the ashes were used as top dressing on clover, the crops were much heavier, earlier, and superior in every respect, to those which had undergone a top dressing with horse and cow-dung. One of the best proofs of their usefulness, indeed, is the fact that, while our crops in this country very often fail, such an instance but rarely occurs in that part of Holland." Sir John adds the public declaration of 83 farmers to this effect, "that they knew by experience, that when clover is not manured at the rate of about 19 bushels to the acre, the following crop is very bad, notwithstanding any culture that can be given to the soil; whereas they always have an excellent crop of wheat after clover," and, doubtless, in proportion to the quantity of manure above-mentioned being used. The analysis of these ashes, given above, sufficiently accounts for their fertilizing property, as they are rich in sulphate and muriate of soda, and sulphate of lime (gypsum). As they are light and black, it is probable that they are not entirely burned but charred, and also contain potash. Charring peat must be very preferable to burning for agricultural purposes, as powdered charcoal has a very beneficial effect upon the growth of plants.

CHAPTER IX.

THE IMPROVEMENT OF SOILS BY MECHANICAL MEANS—DRAINING, SUBSOILING, AND THE ORDINARY MODES OF CULTURE—PLOWING, HARROWING, HOEING, ETC.

DRAINING.

AN excess of moisture in a soil is almost equally injurious to vegetation as a deficiency, and wherever it is manifest, draining is one of the first and most important operations of improved cultivation, without which all others will be rendered almost useless. The constant evaporation which goes on from the surface of wet land, lowers the temperature so much, that the plants are deprived in a great measure of the benefit of that genial warmth so necessary to vegetation, while the coldness and closeness of the soil is unfavourable to those chemical changes which are so essential to the progressive preparation of the food of plants. In wet seasons, also, such soils are constantly washed by the water, which, not being allowed to penetrate the soil, flows off the surface, carrying with it the soluble manures, and thus becomes a serious cause of impoverishment. A redundance of water in the soil excludes the air, the free access of which is indispensable to the germination of the seed and the after progress and development of the plant, as well as to the continued disintegration of the mineral and the decay of the vegetable substances of the soil. In such wet soils the exclusion of the air is not confined

to the rainy season, for the excess of water causes the earthy particles to run together, so that in the drier time which follows, the soil becomes a compact and solid mass, which neither the air nor the roots of plants can successfully penetrate, and vegetation languishes from temporary opposite extremes. It is an indispensable condition of the healthy vegetation of cultivated plants, that the soil should be always moderately open, which no diligence of the farmer can effect by the ordinary mechanical means, while he has to combat with an excess of water caused by a retentive and undrained subsoil. The soil is nature's laboratory, and her work is retarded if it be not kept open.

Another ill consequence of the wetness of a soil is the destruction of the wheat plant during the winter season by the action of frost, which causes an expansion of the soil, which, afterwards subsiding, often leaves the plant upon the surface without attachment; not unfrequently the cause of extensive failure of the crop. Such lands are very properly called cold and poor: the cause of their coldness has been mentioned, but their poverty may often arise from the impossibility of developing the riches they actually contain. This unfavourable state is always sufficiently indicated by the weakness and backwardness of the plants on arable land, and the scanty crops and inferior nature of the herbage of grass lands, which are only capable of producing those coarse and hardy plants which afford the least nourishment to cattle. To all such lands, draining is the great indispensable preliminary step of improvement, as it is in vain to apply manure without it, or at least half its effect is lost from the causes above-mentioned.

In order that draining should be most effectual, the drains should be deep, for it is not enough to carry off the excess of water from the surface soil only, while the subsoil remains almost or quite saturated; but by draining the subsoil to a considerable depth, it is rendered capable of withdrawing the water from the upper soil, especially when heavy rains succeed a long continuance of dry weather. Drains should not, therefore, be less than from 3 to 4 feet deep, with intervals of two or three perches, according to the nature of the land and the degree of inclination of the surface. The lower portion of the drains should be made as narrow as they can be cut, and filled up with stones to half the entire depth if they can be obtained, or tiles or pipes laid in the bottom when the former material is not at hand. When either of the above materials cannot be obtained without too great an expense, wood will last a great number of years in such deep drains, and alder, which generally abounds in wet countries, is the most lasting. All kinds of wood in such situations is very durable except at the mouths of the drains, where the air gains access.

SUBSOIL PLOUGHING.

This is one of the greatest improvements of modern times in the art of farming, without which, indeed, the highest powers of the productiveness of soils cannot be developed. By this method of deepening, or rather, loosening the soil without bringing the materials to the surface in the first place, the drainage of wet land is facilitated, and the surface is *quickly* relieved from the effect of

heavy rains. By the same means the air gets access to act chemically upon the materials of the subsoil to effect their disintegration, and the mineral food thus produced is allowed to be taken up by deep-rooted plants and brought to the surface. The soil is in this way, by degrees, rendered capable of deeper surface ploughing without the bad consequences which in many cases result from bringing up the pan or bottom of the furrow, which often proves pernicious to plants until corrected by a long exposure to the air. Thus, by subsoil ploughing the surface is rendered more healthy by a greater drainage when that is desirable, and at the same time a magazine of the inorganic elements of fertility is opened, and a wider range is allowed to the roots of plants to spread in search of them.

It has already been stated, that about 21 per cent. of the atmosphere consists of oxygen, and that it contains carbonic acid gas to the amount of about one-thousandth part by weight; these are absorbed by the now opened subsoil, the iron of which receives a further oxidation which prevents its being injurious to plants, and the silicates are gradually rendered soluble by the action of the carbonic acid. The natural action of these agents upon the surface soil also is greatly increased by opening and exposing it by the various operations of fallowing, ploughing, dragging, harrowing, and hoeing. The common incentive to these labours is the destruction of weeds, but in achieving that object, a still greater benefit is derived by their fertilizing effect upon the soil in the way above described, and previously noticed; so that the spontaneous production of weeds which causes the farmer so much often-begrudged labour, proves a

necessary stimulus to exertions for which he is rewarded by greater benefit than he expects or is generally aware of; by destroying visible enemies he gains invisible friends. But for the tendency of the land to produce weeds or other plants than the farmer wishes to see upon it, there is a moral certainty that the needful tillage for the preparation of the soil by the action of the atmosphere would not be performed, and that the crops would consequently be deficient. These operations have been practised with more or less skill from the earliest times, but the rational explanation of the whole of the benefit derived from them is due to the chemical discoveries of the present age.

Even with all the diligence that can be used in promoting by these means the disintegration of the soil, plants that require much silicate of potash, such as wheat, barley, and oats, soon exhaust the generality of soils of that substance, if grown in succession, and therefore an interval is required to enable the soil to accumulate a fresh supply before such crops can be repeated with advantage. In former times the farmer allowed strong clay land to rest, or gave it what is called a naked fallow, according to the maxim not yet forgotten by grey tradition, "one year of the sun, and one of the sullow (plough);" but in modern practice green crops, which require no silicates, such as turnips, clover, pulse, and potatoes have been introduced, by which the same object has been effected without loss of time. But there are other substances exhausted in soils, which neither time nor fallowing can supply, and can only be restored by manures, which *we now proceed* to consider.

CHAPTER X.

MANURES.

FARM-YARD AND STABLE-DUNG, THEIR PROPERTIES AND MANAGEMENT.

THE term manure, in its widest signification, is applied to all those substances, the application of which to the land serves to increase its power of production. Such a definition would include lime, marl, calcareous sand, burnt clay and peat, which have already been treated of. It will be the object of the present and succeeding chapters to notice the several kinds of substances which are more especially called manures, with some observations upon their chemical nature and fertilizing properties.

A constant course of cropping cannot be maintained unless we restore to the land those substances of which it has been deprived by carrying away a portion or the whole of the produce. All soils under cultivation are continually being deprived of the materials necessary to their fertility, and ultimately become utterly incapable of beneficial production unless their powers are renewed by bringing back to them those elements in the shape of manure of which they have been deprived by the plants which grew upon them, and which had been removed. Some soils, indeed, are so rich as to sustain for a great number of years continued

cropping without any artificial assistance, but a period must arrive when even these will begin to decline in their fertility, and gradually become poor, and will require the same or similar help as those less favoured by nature. This gradual progress of exhaustion has been noticed in the virgin soils of America, which the first cultivators thought inexhaustible, because for a great number of years they saw no diminution of their crops, which were so abundant that manure was never thought of, and the straw and other refuse of their homesteads accumulated so as to become a great nuisance. This spendthrift system had, however, its termination, and at the present day extensive tracts of the older cultivated lands, which once astonished the farmer by their exuberance, owe their fertility to constant manuring, aided by greater diligence of ploughing and other mechanical operations, with rotation of crops. The first settlers upon a rich virgin soil are not in all cases to be blamed for the neglect of manure; for it is very possible for land to be too rich for the growth of corn crops if aided by a thorough cultivation, therefore neglect of manure and an imperfect tillage are no doubt, in many cases, the best policy to prevent the crops from becoming too luxuriant in the blade to allow of their coming to maturity, by falling before the ear fills.

All plants are composed, as has been before explained, of two distinct kinds of substances, the inorganic or mineral, and the organic; the former they derive from the earth by means of their roots, and the latter partly from the earth, but chiefly from the atmosphere by means of their leaves. All *animals are* supported by plants, either *directly, as those* which feed upon grass, leaves,

and corn, or other fruit; or indirectly, as those which live by preying upon the former, and which may therefore be said to live on plants at second hand. The bodies of all animals, as well as their solid and liquid excrements, are therefore derived from the same sources; when, therefore, we place upon the land dead vegetable substances, or the flesh, blood, bones, and the urine and dung of animals, we return to the soil those inorganic substances (as various salts and earths) which have been derived from it, as well as the organic elements which have been derived from the atmosphere, and which again become capable of entering into new forms of vegetable life, as soon as they have undergone decomposition in the soil, so as to become soluble in water, and thus capable of being absorbed by the roots of growing plants.

Farm-yard and stable manure is composed, generally speaking, of refuse straw, hay, and other vegetable substances, mixed with the dung and urine of animals. In order, however, to form correct ideas of this kind of manure, it will be needful to take some notice of the chemical composition of these main ingredients.

The following analysis of the principal substances, in a perfectly dry state, from which farm-yard manure is derived, is given by Professor Liebig. One hundred parts of each contain—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ashes.
Oats	50.7	6.4	36.7	2.2.	4.0
Wheat Straw .	48.4	5.3	38.9	0.4	7.0
Rye Straw . .	49.9	5.6	40.6	0.3	3.6
Oat Straw . .	50.1	4.5	39.0	0.4	5.1
Potatoes . . .	44.0	5.8	44.7	1.5	4.0
Beet	42.8	5.8	43.4	1.7	6.3
Turnips . . .	42.9	5.5	42.3	1.7	7.6
Hay	45.8	5.0	38.7	1.5	9.0
Red Clover . .	47.4	5.0	37.8	2.1	7.7
Pea Straw . .	45.8	5.0	35.6	2.3	11.3

The ashes consist of salts of potash, soda, lime and magnesia, with carbonic, sulphuric, and phosphoric acids and chlorine, and of silica, oxide of iron and manganese, many particulars of which have been given in the previous analyses of the ashes of several plants. Some parts of these salts are soluble and others not so. It must be evident that the solid and liquid excrements of animals, taken together, must consist of the same substances or elements as the food upon which they subsist; the soluble salts are contained in the urine, and the insoluble in the dung or solid excrements.

The value of farm-yard manure is very much affected by the kind of food given to the animals, when dung and urine constitute a part of it. When cattle or sheep are fed with corn and linseed or rape cake, and horses with oats and beans, the manure is always observed to be more fertilizing, which is owing to the greater quantity of phosphate of lime and nitrogen the seeds contain. This is very remarkable in stable dung, by the fermentation of which the nitrogen forms ammonia, which arises so copiously from the dung-heap, and it is owing to the great quantity of nitrogen it contains that fermentation proceeds so rapidly.

It is interesting to observe that there is an intimate connexion between the life of plants and that of animals, and that the same elementary substances which are necessary to support the former, are equally indispensable to the existence of the latter. Farm-yard dung must afford the most perfect manure for plants, because its elements have all been derived from previous plants and animals which have obtained all their nourish-

ment from them. How important therefore is it, that these valuable materials, upon which the hope and rational expectation of future production must depend, should be preserved and returned to the land with as little loss as possible! for it must be considered that plants have no power of forming the elements of those substances of which they consist. These must either be derived from the ground or the atmosphere; and in proportion as we enrich the former, we enable them to obtain more nourishment from the latter. Very serious waste, however, is often committed by the negligent manner in which farm-yard manure is treated, or the total disregard of it during its accumulation; and when taken from the yard and thrown into heaps, another serious loss is often sustained by excessive fermentation until it is reduced to the state of what is called spit dung.

Let us consider the nature and cause of the loss incurred in each of these cases. By suffering the rain which runs from the surrounding sheds of a farm-yard, in addition to that which falls directly upon the dung, to soak through it and drain away, a very large portion of the soluble salts contained in the urine of the animals is lost to the use of the farmer; a loss which he would not submit to for a single day if he were fully aware of the value of those substances and the amount to which he is deprived of them. Not seeing any diminution of the quantity of the dung, he little suspects that the water does him any injury, while it is daily carrying away some of the most valuable part of his manure, that indeed which has the greatest effect in promoting the growth of plants in their *early stages*. Heavy and continual rains are often

excessively injurious in this way, by carrying off into drains and brooks these precious but overlooked materials.

When dung is thrown into heaps and suffered to remain a long time without further attention, another kind of waste takes place, the result of excessive fermentation, by which a large portion of the valuable organic part of the dung is resolved into gas and vanishes from the sight. The elements of the dung under the influence of moisture and atmospheric air, or rather of the oxygen contained in the air, undergo rapid changes, and enter into new arrangements, by which gases of various kinds are formed and dissipated. There are three conditions necessary to the decay and fermentation of vegetable and animal substances—the presence of atmospheric air, moisture, and a certain degree of temperature; these are all fulfilled in the dung-heap. The process commences with the action of the oxygen of the air, which unites with the hydrogen of the substances to form water; while this action is proceeding, the oxygen of the substances, as well as that of the air, combines with the carbon to form carbonic oxide and carbonic acid, while a portion of the hydrogen unites with the nitrogen to form ammonia, and with sulphur and phosphorus to produce sulphuretted and phosphuretted hydrogen. These all escape as gases, and give evidence of their departure by the strong smell which arises from the fermenting mass. The heat produced is the effect of the chemical action going on, which reacts by promoting the strife of the elements and accelerating decomposition. When the heat subsides and the fermentation ceases, only a black mass of humus *is left, consisting* chiefly of carbon, and

containing the insoluble salts and a small portion of soluble salts that had not been previously separated by the water in the yard, or drained away from the heap. By this process, especially when carried to its greatest extent, a great portion of the most powerful means of fertility is removed, and such is the loss which thousands of farmers sustain without being conscious that they have suffered any. The error of desiring to have rotten dung is perpetuated by the fact, that the manure, thus enormously diminished in quantity, is found to produce a greater effect, weight for weight, at first; which it may well do, from the concentration of the materials which yet remain. Manure, however, reduced to this state will go comparatively but a little way, and though powerful at first, is less permanent in its effects than when fresh or only moderately fermented. The late Earl of Leicester (Mr. Coke) proved the great loss he had sustained by over-fermentation, by observing, that when he discontinued it and used his manure fresh or only slightly fermented, his land produced much more corn than before. Such a result might naturally be expected, from the great waste which attends fermentation as above described, and the still farther loss which in many cases occurs from the exposure of the manure, both in the yard and the heap, to be deluged by rain water, and its most valuable parts carried away.

When fresh stable dung is laid upon grass land early in the spring, or immediately after the scythe, it invariably produces a powerful effect. In this case, both the soluble and the insoluble salts are washed into the ground by the succeeding showers of rain, and immediately come into action, so that

scarcely any of them are wasted. The only inconvenience attending the method of applying fresh dung to pasture land is, that the long straw requires in some cases to be raked off, though much of it is drawn in by the worms. When farm-yard manure is to be applied to arable land, it should only undergo that slight degree of fermentation which is requisite for the destruction of the seeds of weeds, and to render it so manageable as to allow of it being evenly spread upon the land and effectually ploughed in. By this management much waste is prevented, and by a further decay in the ground the manure gradually yields its nourishment to the plants, the growth of which it favours also by its attraction for moisture, and the slight increase of temperature which always attends decomposition.

It is an excellent practice where the folding system is adopted, to cover the ground with unfermented manure, which after receiving the droppings of the sheep is trodden into the ground, and thus is easily turned down and covered by the plough. It is not improbable, that as the art of agriculture advances, it will be found economical to reduce all the straw and hay used upon a farm to the state of chaff, before it is consumed or trodden under foot and receives the dung and urine of cattle. In such case, subsequent mixture would alone suffice to prepare it for the land.

As the welfare of the farmer and that of the country are equally involved in the fertility of the land, and as that will be materially affected by the care taken of farm-yard manure, and the means adopted for its preservation and economical application, every method which enlightened reason can suggest *should be* resorted to for that purpose.

When cattle are kept in open yards, more or less surrounded with sheds, (which is the prevailing custom in England,) each yard should have a firm impervious bottom, for which gravel concrete would be the best material, with a regular but gentle fall from all parts towards the lowest point; at this place a water-proof tank should be formed to receive the runnings or drainings from the manure, which should be covered over and furnished with a pump, for the purpose of either distributing the liquid again over the manure, or pumping it into a water cart, to be conveyed to the land as may be most desirable. The rain water which falls from the sheds should not be allowed to mix with the manure of the yard, but should be conveyed away by shoots. In the summer, or before the cattle are taken into the yard, a foundation should be laid with any rough vegetable matter that can be procured, including peat or tanners' spent bark. During the winter, the stable litter and all other refuse produced on the homestead should be daily and diligently spread, so as to ensure an equal mixture of the substances of different quality. If in addition to all the supplies through the medium of litter, fodder, and green food given to the cattle, they were allowed a little salt every day, both the cattle and manure would be benefited. A still further improvement would be effected by sprinkling occasionally the surface with a little powdered gypsum, at the rate of about one hundredweight, according to the judgment of the farmer, to twenty cart loads of manure, or as many loads as it is intended to place upon an acre of land when carted *out.*

From time to time the drainings in the tank

should be pumped up and conveyed by means of spouts over the surface of the yard, or into a water cart to be conveyed to the land round the homestead. By the careful and constant attention to such rules, the quantity of the manure will be much increased, and its quality improved and rendered uniform, advantages that will repay tenfold the little trouble and expense bestowed upon these valuable materials. To persons in general a heap of manure is an unsightly and disgusting object, but it becomes highly interesting, and particularly so to the agriculturist, when it is considered in the light of a mass of chemical elements, the materials of vegetation, each perfect and beautiful of its kind, and all capable of contributing to clothe the earth with those various forms of vegetation which delight the eye and gladden the heart of every beholder. When the farmer purchases any of these materials from the vender of what is called artificial manures, he is most careful that none of them shall be wasted; he will not allow them to be dropped by the way-side, blown about by the winds, or carried away by water. It can only be from want of knowledge that he is less mindful of the same materials which are contained in his farm-yard manure, when they only want the mind's eye to detect their presence, and to see them vanish into air, or run away in the water. When the manure is carted from the yards to form heaps in the field in preparation for turnips or other crops, a foundation of earth should be previously laid of the extent of the intended heap, and not less than six inches deep. The heap should be regularly formed, with the sides and ends sloping *or inclining* a trifle inwards, and

when the whole is deposited and the top levelled at about the height of five feet, both sides and top should be covered with a coating of earth of the same thickness as the bottom. If the dung has been thrown up lightly, the heap will be in a fit state to turn and mix in about a month or five weeks, and may soon after be carted upon the land, as by that time it will have undergone sufficient fermentation to render it perfectly manageable, so as to allow of it being evenly distributed in the trenches or on the surface of the land, and perfectly covered by the plough. That which remains in the yard, if intended for present use, should be similarly treated, but that which cannot be soon applied to the land, should be carted out and blended with a large portion of marl or good earth as compost, with a covering of earth at the conclusion. By this means a slow decay will be effected with but little waste of materials, and an excellent dressing formed for clover or grass land after the scythe, or for clover ley to be plowed down for wheat sowing. The most valuable material wasted by the excessive fermentation of farm-yard dung is ammonia, which is chiefly derived from urine by the union of hydrogen with nitrogen. By covering the heaps of dung with earth, and mixing them in forming compost, much of the ammonia is prevented from escaping, but a more effectual way of preventing its escape, is by sprinkling the heap during the process of forming it with sulphuric or muriatic acid *very much* diluted with water, as these acids, by uniting with the ammonia as it is formed, would convert it into a salt which has no volatility at ordinary temperatures. This is worth consideration in the preparation of manure, when

we remember that ammonia exercises great influence on the growth of young plants before the leaves are developed, by which they afterwards obtain it from the air. Ammonia produces so much effect upon young plants in the early stage of their growth, that the quantity contained in manures was considered till lately the best test of their value; an opinion which experience and more accurate observation have proved to be erroneous. The acids above mentioned are very cheap, and by using either of them we add a valuable element to the soil. Though ammonia is by no means a safe test of the value of the substitutes for farm-yard manure, yet it is of so much importance to the farmer, that too much care cannot be bestowed to prevent it from being dissipated in the air by fermentation, or wasted by water. This is effectually done by the systematic practice of the use of liquid manure in many parts of Switzerland and Germany, or rather of the liquid and solid excrements of cattle without the straw which forms the other part of our farm-yard manure. This admirable method of preserving the fertilizing power of the excrements of cattle is given by Sprengel, than whom no man could be better aware of its importance, and he relates the practice with so much particularity of detail and explanation, that we cannot do better than state it in his own words.

"In some districts, chiefly on the lake of Zurich, as well as in the west of Germany and Holland, they have for a long time been in the habit of mixing the fluid and solid excrements of cattle with a large quantity of water, in trenches and tanks prepared *especially* for their reception, and

leaving the compound, before applying it for the purpose of manuring fields and meadows, to putrify for a given time, giving it the name of '*gülle*.' The Swiss have a mode, about to be described, of adapting the stalls in which the cattle are kept to the particular purpose of preparing the gülle. In the south of Germany, on the contrary, the method employed is to construct the tanks of gülle in the fields, convey the solid and liquid excrements into them, and mix them in the tanks with water, which they conduct from neighbouring springs, and thus save much expense and trouble in the conveyance of water. In Switzerland, where the preparation of gülle has been longest in use, the cattle stand on a floor covered with planks, bricks, or tiles, and having a slight inclination towards their heels, where a horizontal trench for receiving the excrements runs from end to end. This trench is formed of boards or walling one foot and a half wide and two feet deep, emptying its contents into a tank lined with boarding, six or eight feet deep, and of the same length and breadth, situated either in the cow-house itself, or close to it, and covered with a lid. The horizontal trench being in the first instance half covered with water, the urine runs into it of itself, and the animals drop a part of their solid excrement into this trench, the space allowed for them to stand on being so short, that their hind quarters are close upon the edges of it; so much of it as does not fall into the trench being several times a-day raked in, and the surface well washed with water. The straw litter which has become foul with excrement, is twice a-week removed from under the animals and thrown into the trench, and having been there

well stirred backwards and forwards with the dung rake, is taken out. After it has been in this manner freed from the solid excrement attached to it, and thoroughly washed, it is laid at the edge of the trench in small heaps, in order, in the first instance, to draw out the superfluous liquid; it is then carried out of the building, and formed into regular four-cornered heaps, becoming in a short time so wholly decomposed as to be converted into a dark brown fatty manure, which possesses, however, no particular efficacy, (as may be seen in Switzerland,) deprived as it has been of the best portions of the excrement.

"After the first washing of the litter, the trench is again filled with water, and again, in the course of three or four days, the fresh straw rendered foul with excrement, is washed and put away as before. The trench being at length quite full of liquid, it is well stirred up, the sluice-gate raised, and the whole contents allowed to draw into the tank. The same operations are repeated as long as the tank will allow. In large establishments they now convey or pump the already fermenting gülle out of the tank into a larger reservoir, situated either within the building or outside of it, and before leading it to the fields, they allow it to remain in this reservoir until the fermentation is over, which generally takes place (according to the temperature of the air) in from four to six weeks. When the gülle is applied as a top dressing, care must be taken in pumping it into the barrel in which it is carried into the field, that no agitation takes place, otherwise the undecomposed particles, consisting of vegetable fibre, will lie upon the leaves of the young plants, and *produce an* injurious incrustation.

"In summer it should be applied only in wet weather, otherwise the plants, when the soil is dry, will receive too concentrated a nutriment, and consequently become rather worse than better. We might indeed obviate the evil by a greater dilution of the gülle with water, but the labour of carting it out to the field would then become too much increased.

"On account of the labour of carriage, the gülle, generally speaking, can only be applied to fields and meadows which lie near the homestead, unless you proceed with it as they do in the Black Forest, where the gülle pits are made in the fields and meadows close to them. The most indispensable requisite in the preparation of gülle, as we may suppose, is a sufficient supply of water, and that water is best adapted to the purpose which holds a large quantity of saline particles in solution, for then the soil obtains additional substances which afford nourishment to plants.

"In the Black Forest they always add some green copperas (sulphate of iron) to the fermenting gülle in their tanks; experience having proved that this substance very much strengthens its manuring properties. Of this effect, indeed, we cannot have a doubt, since by its means a portion of the ammonia developed by the urine becomes chemically combined with the sulphuric acid of the copperas, and the resulting sulphate of ammonia, as we know, is one of the strongest saline manures.

"Now, although the arrangement of the cattle stalls, as well as the numerous tanks required in the preparation of the gülle, in order to preserve it for the proper period, occasion much expense, and likewise its distribution over the fields much

labour, these outlays are richly repaid by the advantages derived from the manure, as will be more clearly shown under the following heads :—

"1. The water which is constantly kept in the trench absorbs much of the carbonic acid given out by the cow in the act of breathing; and consequently the ammonia arising from the urine is not only neutralized, and thus rendered less volatile, but the carbonic acid itself is also a strong manuring substance.

"2. The water in the trench serves to keep the cow cool during the heat of summer, and the vapour occasions a dampness in the atmosphere, which is much better for the health of the cow than a hot dry air.

"3. Little, or perhaps none, of the ammonia developed by the urine is lost, its escape being prevented, as my own experiments on the putrefaction of urine have proved, by the large quantity of water present. The absolute quantity of manuring element from this circumstance, is, indeed, very considerable, and fully confirms the statement of the Swiss, that since the time of the introduction of gülle, agriculture has been considerably improved.

"4. By means of the gülle a sickly plant derives almost immediate relief, in consequence of all the nutriment being already dissolved by the water, and in a fit state to enter the plant at once.

"5. It is a point of particular importance, that in adopting the use of gülle, a greater return on outlay of capital is obtained than in the case of common yard dung.

"6. Little or none of the manuring is carried off by the rain, while from the yard manure it fre-

quently happens that much is lost. The practice of spreading it upon the field in heavy dressings renders it subject to this action for three or four years, or even longer.

"7. Plants by means of gülle may be brought to the exact degree of luxuriancy which will yield the most abundant produce.

"8. The growth of forage plants, particularly of clover and the meadow grasses, is greatly secured by the application of gülle, particularly when, (as they do in the Black Forest,) we add green copperas to the putrifying gülle; and the stall feeding of cattle is made more practicable.

"9. Lastly, in adopting the preparation of gülle, less litter is required. When cattle are not properly bedded, much of the manure escapes in the form of gas; while by mixing the excrements with a large quantity of water, little or none of it is lost: it is consequently evident that in the preparation of gülle, a greater quantity of manure is gained than in that of common yard dung; and what is the most important point is, that the gülle has retained a larger portion of that very substance which has the most important influence on the nourishment of plants, namely, ammonia.

"In fact, all the advantages derived from the preparation of gülle are so important, that we cannot but wish that comparative experiments may be made, in order to ascertain with more certainty what is the real amount of gain in the adoption.

"The gülle is conveyed to the field in a barrel placed upon a waggon with iron axletrees, since wooden are soon decayed by being splashed with the liquid. The wheels should have broad fellars, in order not to cut deep when drawn with the

gülle over green crops, pastures, and meadows. The flow of the gülle from the barrel is best effected by a hole, made underneath the centre. Under the hole hangs a board upon which the liquor splashes, and so distributes itself in every direction, in the best manner possible."

The above method, pursued by the Swiss and German farmers to prevent the waste of the most fertilizing parts of their manure, is given in detail, as it affords a practical example in support of what has been previously said on the management of farm-yard manure, and its liability to be wasted by neglect. If this practice has not been directed by scientific views, it is certainly quite in accordance with chemical principles, and it seems is entirely approved by Sprengel, who has devoted great attention to this branch of chemical science.

The above recited practice of the preparation and application of gülle by the Swiss and German farmers, and which is also adopted by the Dutch, is well deserving the attention of the British agriculturist, as it may in many situations be found very advantageous, more especially in dairy districts, where there is generally a deficiency of straw for litter. Notwithstanding the preparatory expense of the first arrangement, there can be no doubt that the practice is highly economical, both as regards the health of the cattle and the preservation of the manure. Of this the continental farmers, who are remarkable for their minute attention to economy, and particularly the Dutch, must have been fully convinced, or they would not have abandoned their former practice of keeping their cows in open sheds and yards, to adopt a system requiring so considerable an outlay.

The straw, which in this practice is removed into heaps and suffered to decay, though when used by itself it would possess inferior manuring properties, must be still beneficial, as it contains phosphate of lime and magnesia, and silica, with salts of sulphuric and muriatic acids.

The solid and liquid excrements taken together contain all the mineral elements which existed in the food, as well as a large portion of the nitrogen. The salts and earthy matter, therefore, of these excrements, may be considered as the ashes of the substances which have been taken as food and have undergone combustion in the body, in the same manner as if the food had been burnt in a fire, the urine containing the soluble, and the solid excrement the insoluble salts. In the latter process, some portion of the organic matter escapes in the form of soot, which may be compared with the unconsumed vegetable matter contained in the solid excrements. The composition of the liquid and solid elements of the horse and cow, are shown in the following analyses:—

HORSE'S URINE, BY VAUQUELIN.

1000 parts contain—

Carbonate of lime	11
Carbonate and other salts of soda	33
Urea (consisting of the elements of ammonia).	7
Water	940
	1000

HORSE'S DUNG, BY JACKSON.

100 parts contain—

Phosphate of lime	5.00
Carbonate of lime	18.75
Phosphate of magnesia	36.25
Silica	40.00
	100.00

COW'S URINE, BY BRANDE.

Chloride of potassium and sal ammoniac	15
Sulphate of potash	6
Carbonate of potash	4
Carbonate of lime	3
Urea (consisting of the elements of ammonia)	4
Water	650
	682

COW'S DUNG, BY HAIDLEN.

Phosphate of lime	10.9
Phosphate of magnesia	10.0
Phosphate of iron	8.5
Lime	1.5
Gypsum	3.1
Silica	63.7
Loss	2.3
	100.0

The mineral elements exhibited in these analyses have been taken from the soil in the various kinds of vegetable substances upon which the animals have fed, and must be all restored if we would keep up a profitable degree of fertility. They are indeed the most essential parts of farm-yard manure, as well as of all others upon which any dependence can be placed. The combustible part of the vegetable substances given to the animals as food have been consumed in their bodies, that is, have been converted into carbonic acid and water, which have passed off by the skin and lungs, but all the mineral substances, with part of the nitrogen, (except such portion as has been retained to increase the size of the animals,) are returned in the excrements, which it should be the sedulous care of the farmer to preserve from waste.

CHAPTER XI.

NIGHT SOIL—GUANO—BONES—BLOOD—PIGEON'S DUNG—RAPE CAKE—BRAN—CHARCOAL POWDER—SEA WEED—CHARRED PEAT—MALT DUST—KELP—THEIR OPERATION AS MANURES—THE INEFFICIENCY OF PARTIAL OR IMPERFECT MANURES.

NIGHT-SOIL is the most fertilizing manure that can be applied to land, because it contains in the most concentrated form all the more important elements or substances which enter into the composition of plants, so minutely divided as to undergo very rapidly the needful preparatory chemical changes. The following analyses of the solid and liquid excrements which constitute night soil are given by Berzelius.

100 parts of the solid excrement when burnt yielded rather more than 15 parts of ashes, which consisted of the following salts:—

Carbonate of soda	3.5
Muriate of soda	4.0
Sulphate of soda	2.0
Phosphate of magnesia	2.0
Phosphate of lime	4.0
	15.5

1,000 parts of urine contained:—

Water	933.00
Urea (consisting of the elements of ammonia)	30.10
Salts of ammonia with some animal matter	18.46
Sulphate of potash	3.91
Sulphate of soda	3.16
Phosphate of soda	2.74

Phosphate of ammonia	1.65
Muriate of soda (common salt)	4.45
Muriate of ammonia	1.50
Earthy matter, lime and silica	1.03
	1000.00

By fermentation of the urine, which soon takes place when exposed to the air, the urea is converted into ammonia, which, with that contained in the salts, accounts for the great quantity of that substance afforded by urine, and the pungent smell for which fermenting urine is so remarkable.

Considering the valuable materials of which night soil is composed, and its well-known effect in promoting vegetation, every means should be taken for its preservation; but it is very remarkable that in a country like England, whose population is every year rapidly increasing, and which is obliged to depend upon foreign nations for a supply of corn, little or none of this valuable manure is preserved. To speak only of one ingredient, phosphate of lime and magnesia, (bone earth,) thousands of tons are thus annually thrown away, while we are importing bones from the continent, though not to the hundredth part of the amount of that which is wasted. While we suffer night soil to be carried away by water, to pollute our streams and contaminate the air with fetid and poisonous exhalations, we bring guano, a manure of precisely similar elements, only in a more convenient form, from the remotest parts of the world. The Chinese, the most skilful people on the face of the earth in the management and application of manures, have from time immemorial taken the greatest care in the preservation of night soil, and *their* principal method is by blending it

with marl and forming it into balls, which they dry in the sun, and in this state it forms a great article of commerce. In France and other parts of the Continent, the soil of the great towns is dried in the sun and sold under the name of "poudrette." This mode, however, is very offensive and objectionable, as the greatest part if not the whole of the ammonia is dissipated. Within the last few years some endeavours have been made in England to prepare night soil for manure by a process which is called disinfective,—that is, by mixing it with certain substances which have the effect of destroying its offensive smell, and subsequently drying it. A sewage company has also been lately established with the object of collecting the drainage of sewers, and distributing it by means of pumps and pipes to the surrounding land. If this can be economically effected, it will afford the means of supporting in the highest state of fertility many thousand acres, as has been proved by what has been done round Edinburgh, though by a more simple method. Night soil may be rendered inoffensive by mixing it with any of the following substances; powdered charcoal, charred peat, very dry peat or coal ashes, and burnt clay. Fresh soot also has a similar effect. Whichever of them is used, it should be in the greatest possible state of dryness, and fresh from the action of fire. Some of the above materials are obtainable in almost every situation. After well mixing, the mass should be exposed to the action of the sun and air under an open shed, and when dry sifted for use. Lime has been used as a deodorising substance, which, however, it effects at the expense of the ammonia, which it entirely dissipates.

Guano, the dung of sea-fowls, is found on the rocks near the coast of Peru and some parts of Southern Africa, where it has been accumulating for ages. The ancient Peruvians, who were an agricultural people at the time of the Spanish invasion, were so fully aware of the great value of this manure, that strict laws existed against the disturbance of the birds which frequented those rocks in enormous flights. By means of this manure alone, the barren sands of the Peruvian coast were rendered highly fertile more than three hundred years ago, but it is only very lately that its excellent quality became sufficiently known in Europe to induce merchants to import it; since which time thousands of ship-loads have been brought to England and eagerly purchased by farmers, at first at an enormous price, but afterwards, when the trade became more general, at moderate rates. On the coast of Peru no rain ever falls throughout the year, so that the guano suffers but little from exposure to the air, as it dries and consolidates as fast as it is deposited. It must, however, in time, lose a considerable portion of its ammonia, and become from that cause less valuable. Of this the Peruvians were fully sensible, and therefore always used that which was the most recently deposited. The immense demand for guano for the British market prevents any such discrimination being used by the shippers, which will account for the difference in value of the cargoes brought from the same rocks. The guano brought from the coast of Chili and South Africa, where much rain falls, is of very inferior quality to the Peruvian. The enormous consumption of this *most valuable* manure is fast wasting the accu-

mulated stock at all these points, and in a few years must entirely exhaust it, an event which will render it more imperative to prevent the waste of equally valuable native manure, and cause a more strict attention to every source of fertility that has hitherto been neglected, or at least attracted but too little notice.

The following analysis of a Peruvian guano is given by Voelkel:—

Urate of ammonia	9.0
Oxalate of ammonia	10.6
Oxalate of lime	7.0
Phosphate of ammonia	6.0
Phosphate of magnesia and ammonia	2.6
Sulphate of potash	5.5
Sulphate of soda	3.8
Muriate of ammonia	4.2
Phosphate of lime	14.3
Clay and sand	4.7
Animal substances, with a small quantity of iron and water	32.3
	100.0

By comparing the analyses with those of human excrements previously given, it will be seen how much they resemble each other in chemical constituents: both contain in a high degree of concentration all the most essential elements of fertility, to which and their minute state of division, and consequent ready solubility, they owe their forcing and powerful effect.

The great recommendation to guano is its very convenient form, and the large quantity of phosphate of lime and ammonia which that of the best quality contains.

Guano is often much mixed with sand, which *may have* been blown upon it during its deposition;

but Dr. Ure, who analysed many specimens, says, that the proportion of sand in genuine guano seldom exceeds 2 per cent. When a good specimen of guano is burned in a shovel or iron ladle over the fire, it leaves a white ash of phosphate of lime and magnesia; whereas if the guano contain much sand and sea-salt, a fused mass of these substances will also be found. A simple method of testing the genuineness of guano, which any farmer may easily practise, is by ascertaining its specific gravity, which in that of good quality seldom exceeds 1.66, that of water being 1.00. This may conveniently be done with tolerable accuracy in the following manner. Take an ale glass, or what is better, a large phial bottle, and having balanced it in a small scale by a weight placed at the opposite end, pour into it an ounce of water; mark accurately the height at which the water stands; having done this, add another ounce by weight, again marking the place to which the water rises; now pour off the second quantity, leaving the water at the mark indicating an ounce. In place of the water poured off, drop in as much guano previously dried as will raise the water to the two-ounce mark, and then ascertain the weight of the contents of the vessel. If it weigh more than 2¾ ounces, it indicates that the sample contains too much earthy matter to be genuine, or of the best quality. The excess of weight may be owing to sand or other earthy impurities, or sea-salt. It may also be owing to an excess of phosphate of lime, caused by the decay of the guano from time and exposure to rain, by which the ammonia and other organic matters may have been destroyed.

Genuine *guano* when fresh is of a pale drab colour,

but becomes of a reddish brown colour by age and exposure. When guano is very moist, it may be suspected to have sustained much injury, and at all events the quantity of water should be ascertained by first weighing and then drying it at the heat of boiling water. Dr. Ure found that a very good specimen of Bolivian guano of a pale yellow colour lost only 6½ per cent., while a cargo which sold for a high price had more than 22 per cent. of water. Guano of the best quality has a strong scent resembling smelling salts, and when moistened and mixed with quick-lime, emits very pungent fumes of ammonia. The intensity of the fumes, however, is by no means a sure test of comparative value, as in the best specimens the larger quantity of nitrogen, the essential element of ammonia, exists in a latent or unformed state, and is slowly given out by the action of air and moisture—in fact, by decay.

Two hundredweight of good guano is quite equivalent to 18 or 20 cart loads of farm-yard dung, in its effect upon the first crop. When used, for more regular distribution, it should be thoroughly mixed with at least an equal weight of coal or peat ashes. If charred peat, powdered charcoal, or more especially wood ashes, be used for this purpose, the efficacy of the manure will be much increased. The guano thus prepared may be either sown broad-cast, and harrowed in with the seed, or delivered in drills at the same time with the seed. Applied to barley, it is found to effect a great increase of the succeeding clover crop, far exceeding the cost of the guano. When *sown* upon clovers, it should be done just before *rain, or* in default of rain the water-cart should be

used, otherwise it is apt to injure the leaves of the plant. On pasture land it produces a great effect, applied at the rate of from 2 to 5 cwt. per acre.

Bones, much broken or reduced to powder, have for some time past been very extensively used as a manure, and with extraordinary effect, chiefly owing to phosphate of lime, their principal component part, and of which large quantities are continually drained from the soil in the shape of marketable produce. According to Berzelius, 100 parts of dry ox bone contain:—

Cartilage or gelatine	33.30
Phosphate of lime	58.35
Carbonate of lime	3.85
Phosphate of magnesia	2.05
Soda, muriate of soda, and water	2.45
	100.00

Besides the above substances, the *fresh* bones contain a considerable quantity of oily or fatty matter, which retards their decomposition in the soil, and their more immediate effect upon crops; and this has led to the conclusion that they are less efficacious than when previously boiled and calcined; but this must be an erroneous inference, for the gelatine or jelly contains the elements of ammonia, as well as other nutritive substances, which cannot fail to produce a good effect as it undergoes decomposition, and therefore fresh bones, though slower in action, must in the end be more beneficial. When bones were first applied as a manure, the effect was astonishingly great, which, however, admits of an easy explanation, when we consider the large quantity of bone earth (phosphate of lime and magnesia) which is

continually removed from the soil, and carried away from a farm in the shape of corn, cattle, wool, and milk, by which it must become very much impoverished in that particular and very essential substance, which if quite exhausted, would render the soil incapable of producing *seed* crops. It must be obvious, that in the ordinary way of manuring with farm-yard dung, without any foreign aid, there must be less phosphate of lime returned to the soil than has been taken from it, by all the quantity contained in the saleable produce above mentioned. This drain, in a course of years, would cause a very great deficiency of bone earth in the soil, and a corresponding decrease of the crops, both of corn and grass. In this state of deterioration were most of the soils of England when bones were first brought into use as a manure, and the surprising effect produced by their application manifested the extent to which the soil had been impoverished of this particular substance. It will not, however, supply the place of other materials, for if applied to a poor and exhausted soil, its effect would be inconsiderable, and if repeated several times, even on a good soil, it soon ceases to produce any adequate effect, because it is in abundance in the soil, more than the crops require, and other substances equally essential to fertility have become exhausted.

The more bones are broken down before they are applied to the soil, the quicker will be their effect. They are usually applied at the rate of from 8 to 16 bushels per acre, but it is more than probable that less than half the quantity would suffice if drilled upon the farm-yard dung, to which it must be considered as a help, not a substitute;

for in applying bone earth, we must consider that we are only returning that in which the dung is deficient, to the amount of that which is carried away in marketable produce, which is far less in a course of four or five years than the last-mentioned quantity, though on the first application, after long-continued impoverishment, a larger quantity becomes necessary. In all cases, however, it is better that it should be in excess than deficient in quantity, and the quantity actually required must depend upon the quantity and quality of the farm-yard manure used with it. When the latter is of uniform quality, a few carefully conducted experiments would suffice to show how much of this expensive manure is actually required to maintain, as far as bone earth is concerned, the greatest degree of productiveness of which the land is capable.

Blood, as containing all the constituents of animals, affords an excellent manure, and has a very forcing effect upon vegetation: it is obvious, however, that it can only be applied to the land in some state of mixture with other substances, as a compost, of which it will form a most valuable ingredient. The most available and economical form in which blood has been applied to the soil, is that of sugar refiners' waste, in which it is mixed with animal charcoal (burnt bones) and lime. This refuse contains about 20 per cent. of blood, and has risen to an enormous price, especially in France, where it has obtained the name of animalized charcoal, or animal black. The great demand for this excellent compound has led to the preparation of night-soil as well as blood, with charcoal powder, which are *sold by the* same name.

As the object of all cultivation is the nourishment of animals, and as that nourishment is conveyed through the medium of the blood, it must be obvious that blood must contain all the substances from which the bones, flesh, and skin of animals is formed, which having been derived from plants, affords them again, when applied to the soil as manure, the same nourishment that other plants had before collected from it.

Horn, Hair, and *Wool,* contain nearly the same ingredients as blood, but with more phosphate of lime, and therefore afford similar nourishment to plants in a more condensed form, inasmuch as they are in a dry state, but yield it more slowly, from the time required to effect their decomposition in the ground. Of this kind of manure, woollen rags is the only kind available to any considerable extent, 8 cwt. of which applied to the potato crop, will have an equal effect with 20 cart loads of farm-yard manure. This kind of manure is best suited to light and sandy soils, in which it more readily undergoes decomposition, from the free admission of air beneath the soil. When used, they are chopped small and distributed with the potato sets in the trenches.

So much is this kind of substance esteemed in China, where no animal manures are allowed to be wasted, that even the shavings and hair of the barber's shop are scrupulously preserved.

Pigeons' Dung is a very rich manure, as these birds feed almost exclusively on corn. When mixed with soot and wood ashes, it forms an excellent top dressing for reviving, as far as it goes, wheat which has been very much thinned in the course of the winter by frost or the wire-worm.

Soot often affords a valuable resource to the farmer, when his wheat has been weakened or the plants diminished in the manner above mentioned, upon which it is sown with a hand scoop, at from 20 to 50 bushels per acre; it consists chiefly of finely divided charcoal and sulphate and carbonate of ammonia, but differs in quality according to the coals from which it is derived. If a handful of soot be moistened with water, and a little quick lime added, it will emit very strong fumes of ammonia.

Newcastle coal affords soot of the best quality, but the soot of London derived from it is, however, often very much adulterated with fine street dust: this is easily detected by mixing it with water, and then suffering it to stand a short time, when the heavy adulterating matter will soon subside. Though soot has been almost always used as a top-dressing, it is certain it would have a most beneficial effect if used as the ingredient of a compost with other substances for drilled crops, in which way it has been successfully employed. Rape cake, and wood or peat ashes, and salt, would be valuable additions. It appears by a recent experiment recorded in the "Royal Agricultural Journal," that 54 bushels of soot mixed with 6 lbs. only of common salt, produced larger crops of carrots than 24 tons of stable manure, or 24 bushels of bones. Carbonate of ammonia being one of the most essential ingredients of soot, by thinly spreading it over the land as in top dressing, a considerable part of that valuable substance must be lost, and mixing it with lime, as some persons have recommended, must be still more injurious, as that substance causes its rapid dissipation.

When used as a top dressing for wheat, the land should be hoed immediately after the soot is spread. The effect of soot upon thin wheat is very striking; the plant soon acquires a dark green colour, and begins to tiller and spread with great vigour. It is therefore one of the best means to which the farmer can have recourse to improve a thin plant.

Rape Cake is much used as a manure, at the rate of about 5 cwt. per acre; and, as it is rich in phosphate of lime, its fertilizing property is probably chiefly owing to that substance.

Bran of Wheat is a good manure of the same kind. It is recommended, by high authority, for potatoes, as it contains much phosphate of magnesia, which that crop requires. Injured or refuse bran might be profitably used for that purpose.

Malt dust, or the screenings of malt, is much recommended as a manure, and is considered equal to rape dust. It must be rich in saline matter, as young shoots always are, as well as in nitrogen, and no doubt owes its effect to these ingredients.

Charcoal Powder.—This substance has the power of absorbing ammonia and oxygen from the air, and it is to this property that it owes its effect as an antiseptic and in purifying water. When well supplied with water, it causes rapid vegetation in plants, and the smallest cuttings placed in it readily take root. Its fertilizing effect cannot create surprise, when it is considered that, in addition to its power of absorbing ammonia and oxygen, it contains the ashes of the plants from which it is made, which, taken together with the elements of water, constitutes an assemblage of all the elements that enter into the composition of plants.

Charred Peat, which has been before incidentally mentioned, may be considered only as another form of charcoal, and must owe its beneficial effect to the same properties. Both this and charcoal are excellent ingredients in artificial manures, and especially such as contain putrifying animal substances of any kind.

Sea Weed is often available on the sea coast, and is said to enhance the value of land on some parts of the coast of Scotland from ten to twenty shillings per acre. It is applied every second year, in a fresh state, to the land, which sustains by its aid a severe course of cropping. It owes its fertilizing effect to the sea salts it contains, which include, as before stated, all the inorganic or mineral elements of plants.

Kelp or Varec, the ashes of sea-weed, has been long used in Normandy and the Channel Islands with great profit as a manure, and is remarkable for producing the finest samples of grain. The essential properties of kelp are the same as those of sea-weed, from which it is produced, and it contains a large quantity of potash as well as soda, which have been produced by the decomposition of the salts of the sea. Wherever sea-weed can be procured in great quantities, it might be made a valuable article of commerce for the purposes of agriculture, by being charred instead of burnt, so as to preserve nearly all the carbon; in this state it might be packed in casks and sent into the interior. Few manures contain, in the same compass, so much fertilizing matter as would be found in charred sea-weed thus prepared; and, when mixed with bone dust, it would form an excellent compound *for drilling* with turnips.

CHAPTER XII.

GYPSUM, SULPHATE OF LIME, OR PLASTER OF PARIS—NITRATE OF SODA—EXPLANATION OF THE CAUSE OF THE FAILURE OF CERTAIN PARTIAL MANURES.

This salt derives its latter name from being found in vast quantities in the vicinity of Paris; it exists also in rocky masses in the red soil of Nottingham, Somerset, Worcester, and Cheshire, and is found dispersed in the London clay in a crystallized form, in which state it is called silenite. Eighty-six parts of gypsum contain:—

Lime	28
Sulphuric acid	40
Water	18
	86

It dissolves with difficulty in water, requiring 500 times its weight of water to effect its solution. When calcined, the water of crystallization is driven off, and it then takes the form of a very white powder, in which state it is sold to plasterers. When the powder is again mixed with a proper proportion of water, the mass heats and sets immediately, and in this way is used for making the beautiful mouldings and ornaments of walls and ceilings. The gypsum found in large quantities exists in masses of irregular shape, but the silenite presents regular transparent crystals, which are capable of being split into exceedingly thin plates.

Gypsum has been much used, in a powdered

state, as a top dressing for clover, sainfoin, and grasses, and in numerous instances with great effect, but also very frequently without any perceptible benefit. Both the success and failure admit of a very easy explanation. It is constantly found in the ashes of many plants, particularly in clovers, and therefore may be considered as indispensable to them. Many soils contain a large quantity of this salt, in which case its artificial application will be perfectly useless, and produce no effect; while in other soils it may be naturally deficient, or nearly absent; and if such soils happen to be in good condition in other respects, it will in such instances have great influence, especially on clover and pulse crops, so much so as, in some recorded cases, to increase the produce four-fold. It requires considerable chemical skill to ascertain the presence or absence of gypsum in a soil, and the farmer can only know it by experiment, that is, by sowing it upon small patches of clover or pulse to try the effect before he incurs the trouble and expense of an extended application. Such is its deficiency in Canada, that the effect of sowing so small a quantity as two cwt. per acre on the clover plant is almost incredible. The effect of coal and peat ashes upon some of our soils, especially the green sand, is most probably owing to the sulphate of lime those ashes contain, as the clover plant is astonishingly improved by their application. Gypsum is of great benefit in soils by fixing the ammonia of the atmosphere, or that derived from the manure applied to them, and thus preserving it for the use of plants. In such cases the gypsum is decomposed, the ammonia uniting with its sulphuric acid and forming a sul-

phate of ammonia, which has no volatility, while the lime unites with the carbonic acid of the ammonia, and remains in the soil as a carbonate.

Gypsum and common salt act upon each other, by which they are mutually decomposed; the sulphuric acid of the gypsum uniting with the soda and forming a sulphate of soda, and the muriatic acid of the salt combining with the lime to produce muriate of lime. By such decompositions as these, which take place in the soil or plants, the latter derive the sulphur they possess, and which some contain in considerable quantity, such as turnips and cabbages, mustard seeds, onions and horse radish. Thus gypsum is beneficial to plants in three ways; first, in its entire state, as part of their mineral food; secondly, by attracting and detaining ammonia; and thirdly, by its decomposition, in yielding sulphur.

By strewing the floors of stables with powdered gypsum, the ammonia arising from the urine of cattle is fixed, and thus prevented from infecting the air with pungent exhalations, an effect so desirable both for the health of the animals and the preservation of a most fertilizing substance. Mixed with the manure of the farm-yard, it will have a similar effect when it begins to ferment, or thrown into tanks containing the urine of cattle. Whether gypsum be found in the soil, or be artificially applied, it must always play an important part in their fertility; as a soil destitute of gypsum, or its constituents, lime and sulphuric acid, would be incapable of sustaining crops.

The following extracts from the "British Husbandry" exhibit several striking instances of the *beneficial* effect of gypsum upon soils:—

"In Scotland, and in many other parts of the United Kingdom, gypsum has been found nearly inefficient; yet, on Mr. Coke's farm in Norfolk, great benefit from applying it in powder at the rate of four bushels per acre on sainfoin layers, the crops of which are said, in some other instances, to have been doubled. In some experiments made in Kent, and recorded in the communications to the Board of Agriculture, it also appears to have been employed with such advantage on calcareous sandy loam, and even on stiff soils which had been previously chalked, that it is said to have increased clover and lucerne three-fold, and to have proved equally beneficial to leguminous crops. Thus it has been stated, by Mr. Smith of Tunstall, near Sittingbourne, that having a field of red clover which had been manured with gypsum, and had produced a very fine crop, he carefully repeated the trial on two square perches; one spread in the middle of April with powdered gypsum, at the rate of five bushels to the acre, and the other without any; the result of which experiment upon the crops per acre, when mown for hay and afterwards cut for seed, was as follows:—

	CWT.	SEED.	STRAW OF THE SEED CROP.
Gypsum	60	3.21	22.3.12
No manure . . .	20	0.20	5.0. 0

The cost of the gypsum was then five shillings per bushel, though it is now much less, and he values the difference between the two crops at not less than 16*l.* 2*s.* 9*d.* in favour of the experiment."

"The same person says that cattle show such a remarkable *predilection* for clover which has been

gypsumed, that, after having once tasted it, they have been observed to walk deliberately to it the whole length of a field without tasting that which was grown without, though a tolerably good crop; and, in his opinion, it not only increases the vigour and the verdure of the plant, but also perceptibly increases the juices.

The following experiments upon its application comparatively with ashes upon different perches of clover afterwards cut in full head, also show it to have been attended with superior effect.

	lb.	oz.
No. 1. No manure	38	6
2. Four quarts of sifted Coal ashes, which had not been exposed to the weather	50	0
One quart of gypsum	54	0

Nos. 1 and 2, sprinkled separately with one and two quarts of gypsum.

Nos. 3 and 4, sprinkled separately with three and four quarts of ashes.

No. 5, sprinkled separately with five quarts of wood ashes.

The produce of Nos. 1 and 2 was equal and superior to those of 3 and 4, and that of No. 5 was the worst; but each patch, when compared with the adjoining land, which had no manure, was not only considerably higher, but thicker, of a deeper and more luxuriant colour, and of a broader leaf.

In various other repeated trials, made with great care on sainfoin, sown upon poor light chalky land, the several results show a considerable balance in favour of gypsum; "the hay crop yielding so abundantly as to exceed that upon which it had not been laid, on an average, 44*s.* per acre; it likewise afforded a proportionate increase on sheep

pasture; and when sown with peas, when looking up it generally produced immense crops. It has been applied, at the rate of five bushels per acre, with similar success to clover, on a certain portion of land in the middle of a large field, where the soil was of the same quality; the entire field was then sown, in the following November, with wheat, the appearance of which, both in colour and strength, upon that part which was gypsumed, became very apparent in the month of May, and was so striking at harvest that, when separately reaped, threshed, cleaned, and measured, under careful inspection, the following was the result:—

	QRS.	LBS.		£	s.	d.
Gypsumed produced per acre	4	6	at 72*s*.	17	2	6
No manure	2	4	„	9	0	0

three quarters per acre having been the largest crop ever before grown upon that field during twenty-eight years that it had been occupied by one person, when wheat had followed beans, peas, and trefoil, in the common course of husbandry. When thin upon the ground, clover, if top dressed with uncalcined gypsum, at the rate of five or six bushels to the acre, according as the plants have been more or less thin, has been found to stock out with such luxuriance, that a difference of a load an acre has been observed between that and the same crop on land of the same quality which had been left without manure. We learn from Russell that it had been laid on a neighbour's farm in Warwickshire, in the end of April 1830, at the rate of about three bushels to the acre, and that when mown on the 21st of June following, there was *an astonishing* improvement of the crop

in that part of the field which had been so dressed. Its application to lucerne has also shown it to be of equal effect."

NITRATE OF SODA.

This salt is found in vast quantities in South America, from whence it is imported for various purposes in the arts, particularly in the manufacture of sulphuric acid, which is effected by burning it in contact with sulphur in close vessels. It has been strongly recommended and much used as a manure, in some instances with great success, but in many with but little observable effect. Its frequent failure has given rise to much speculation as to the manner in which it effects crops, whether its beneficial effect be owing to soda or the acid, though there can be no doubt that both are instrumental in promoting the growth of plants, when the other necessary conditions of fertility are fulfilled, and its frequent failure can only be explained by the supposition that some other mineral element of nutrition was at the same time deficient. Nitrate of soda, therefore, must be considered as one of those partial manures upon which no safe reliance can be placed, the application of which has caused, and continues to cause, so much perplexity, disappointment, and loss to the farmer. If we expect the land to be fertile, we must take care that all the *conditions* of fertility be fulfilled. Nothing is produced out of nothing. We have seen that plants and their seeds consist of certain organic and inorganic elementary substances, in all 14; the former, namely, oxygen, hydrogen, carbon and nitrogen, are derived by plants from

the atmosphere, the latter from the soil, and if they be all present, the conditions of fertility are fulfilled, as far as the food of plants is concerned. When the farmer places upon the land his farm-yard or stable manure, he returns to it all the substances, both organic and inorganic, of which plants and their seeds are composed, and which had been previously taken from it; and he is seldom disappointed of their effect; but if he relies for the support of the fertility of the soil upon the application of only two or three of these elements in the shape of a single salt, he must encounter frequent failure. Without knowing or considering of what materials plants are composed, or that many different substances are required to fulfil the conditions of their growth, he applies an individual salt, and if it happen to be the very substance that was deficient in the soil, he gets a crop. With the assurance afforded by this fortunate success, the same salt is applied to another field, with the full confidence that it will produce a similar effect; in the latter instance, however, to the great surprise and disappointment of the farmer, it proves a failure. Others try the same salt with various success, and frequently with little or no perceptible advantage, until, experience having taught that no dependence can be placed on this particular salt, it is finally abandoned. This has been the fate of all such partial manures, or attempted substitutes, in which we may include common salt, gypsum, carbonate of soda, nitrate of soda and nitrate of potash (nitre), each of which in its turn has been raised into importance by a few instances of successful application, and has afterwards, from expecting too much from it, fallen into undeserved disfavour, as each of them is good

for the soil, though by itself it cannot be relied upon.

If any one of these salts be absent from a soil which contains all the others required by plants, its application will then have a great effect; and if it be only deficient, it will produce a greater or less improvement in the crop. If, on the contrary, it be already abundant in the soil, no benefit can be expected from it, and it will also fail if some other substance equally required by plants, be wanting or very deficient. Under the most favourable circumstances, that is, of the single salt applied being the substance that was absent or very deficient, and therefore proving beneficial, it hastens the exhaustion of other elements, the presence of which in the soil is equally necessary. The abundant crops of wheat produced by the first application of bone-earth was owing to the previous exhaustion of that substance in the soil, through a long series of years, in which more had been constantly carried away in the crops than had been returned in the shape of manure. The instances in which it produced its greatest effect were, no doubt, those where there was no deficiency in other respects, and where the soil was in a high state of cultivation. That the great benefit derived from the use of bones (phosphate of lime and magnesia) has been more general than that of any other single salt or partial manure, is owing to its being less abundant, in all soils than many others, such as gypsum, common salt, and salts of soda and potash, and not having been, from causes above-mentioned, returned in an equal degree in the shape of farm-yard manure. But even bones have been applied in excess, until they no longer

produced any effect. The expression used in such cases of failure after success is that the land has become sick of it, but the truth is, that it wants no more of it, or is deficient in some other substance. The occasional success and failure of these very partial manures, and the serious loss often attending an extensive application of them, have led the more reflecting agriculturists to the conviction, that other knowledge than that which farmers generally possess was requisite to explain their causes, and have called into the field the aid of chemical science. Neither plants nor animals can live, unless their food contains all the elements of which their bodies consist. When a dog is fed upon flesh, it enjoys vigorous health; but if jelly alone be given it, which contains only a part of the elements of its body, death soon ensues. Again, it will live and do well upon undressed wheat meal, but rapidly declines if kept upon flour from which all the bran has been removed. In Russia, a horrible punishment has been inflicted upon malefactors, by giving them food perfectly deprived of common salt, which after producing lingering disease proves fatal. The application of farm-yard dung to plants is like giving flesh to the dog, because we administer in that form all the substances which the plants require; but when the farmer applies a single salt, it resembles the attempt to support the dog with jelly or fine flour; at all events, he throws himself upon the chance and uncertainty of all the other salts which plants require being already in the soil. The frequent failure of such practice ought no longer to excite his surprise.

When a substitute is required for farm-yard manure, as the *farmer* cannot with certainty know

what are the particular deficiencies of the soil, he should use one which contains, if not all the substances included in his proper manure, at least those which are likely to be the most deficient; and these in ninety-nine cases in a hundred will be bone-earth, salts of soda, potash, and ammonia. These might be supplied by a mixture of soot, bone-dust, and wood or peat ashes; if the latter is used, it should be in large quantity. Many heavy or clayey soils contain gypsum, and common salt is seldom deficient in those near the sea, and it is on such soils that these often fail to produce any effect when separately applied. But as the presence of these salts cannot be ascertained without an analysis, and as they are very inexpensive, they should not be omitted in a mixture intended as a substitute for a more perfect manure, as their presence is indispensable. Oxide of iron, carbonate of lime, magnesia, silica and alumina, the remaining mineral constituents of plants, as they constitute the great bulk of soils, are never so deficient as to be wanting for the mere food of plants. From what has been stated above, it must be obvious that any single salt cannot be relied upon as a manure: it may be sometimes an available accessory, but cannot serve as a substitute for those more perfect manures produced by the decay of vegetable substances and the dung and urine of cattle, such as stable and farm-yard dung, guano, and night soil. Many soils may become exhausted of some one mineral substance, even when supplied with farm-yard dung in the usual course, as we have seen has been the case with bone-earth; it may likewise occur with regard to gypsum and common salt; in such cases their application will often be attended with great

benefit. It may here be observed, that if common salt were given to cattle and sheep, which is so beneficial to them, and gypsum were used in stables and urine tanks as before recommended to prevent the escape of ammonia, there would be no deficiency of these substances in soils regularly manured with farm-yard dung.

CHAPTER XIII.

COMPOSTS, THE VARIOUS MIXTURES COMMONLY USED FOR MAKING THEM, AND THE MODES OF PREPARATION—PARING AND BURNING, EXPLANATION OF ITS EFFECT ON SOILS—IRRIGATION.

THE mixtures of different substances for manures, called composts, are of very variable character, according to the materials used, or of which they are formed. Every cultivator, whether upon a large or a small scale, from a large farm to a small garden, should have some manufacture of this kind going on, as for the most part it consists of rubbish and raw materials, which would otherwise be wasted or neglected, and in many cases to the injury of health. It frequently occurs that the whole of the dung of a farm cannot be used at the proper or most desirable season, and that some part must be reserved for some future opportunity; care therefore is required that it be not wasted by fermentation, or the action of water. Such manure is a proper subject for forming compost, which is done by mixing it with any kind of soil which happens to be most convenient. It is, however, by no means an unimportant question as to what material is best adapted to the purpose. The mud of ponds, the clearing of ditches, and the deposit of tideways are the first to be recommended; and in default of these, road-scrapings, *marl,* or clay are good materials. In forming a *compost* heap, a layer of earth six inches deep

should first be made, of the intended dimensions, then a layer of the dung lightly and regularly spread on it to the depth of a foot; after this, another layer of earth of six inches, and so on alternately till the heap is about five feet high, finishing with earth. In about eight or ten weeks the heap should be turned and thoroughly well mixed, and again covered with a slight coat of fresh earth. In thus mixing the dung with earth to form compost, the three following objects are attained: firstly, the prevention of the too rapid decay of the dung, by which its materials would be wasted; secondly, the detention of gaseous substances, especially ammonia; and thirdly, to afford some addition of saline matter in the earthy material. A small quantity of salt and gypsum would be valuable additions for light and inland soils.

Where good peat abounds, advantage should be taken of it to form compost with farm-yard dung. This is done by mixing the dung and peat in alternate layers of about equal proportions, and finishing with peat. After the heap is thus formed, it should be occasionally examined as to its temperature, and this may be done by keeping a stick in it, which may be drawn out from time to time. When it becomes quite warm, if it be dry, water should be thrown over it, but if tolerably moist, it will be better to turn and mix it well together, when, if the heat be very considerable, more peat may be added; after the second heat has subsided, it should be again turned, when it will soon be ready for use. The benefit arising from this management is the obtaining an additional quantity of humus by the fermentive action of the dung

being communicated to the inert peat, by which the latter is partially decomposed, while the ammonia and other volatile matter, as well as the soluble salts of the dung, are preserved. Lord Meadowbank first recommended this method of fermenting peat, and a Scotch farmer, mentioned by Sir John Sinclair, said that he would cart peat two or three miles rather than be without it for this purpose.

Lime mixed with peat affords a good compost for dressing pasture lands, which would be much improved by the addition of common salt and gypsum, at the rate of about one hundred weight of each to ten cart loads of the other materials. The action of lime upon peat is to break down the inert woody matter, and render it capable of affording organic food to plants, as well as the salts or mineral substances which it affords when burnt to ashes. We have already mentioned an excellent compost produced by peat and lime slaked with brine, and also peat saturated with sea-water and fermented with lime.

When lime is mixed with marl or clay, it is very beneficial to pasture land, which may be accounted for by the action of lime effecting the liberation of potash, which all clays contain, as already explained under the head of lime; besides which, every fresh supply of these materials affords other mineral substances required by plants. All refuse animal and vegetable substances are most valuable materials for making composts, and the greatest attention should be devoted to preserve and mix them so as to prevent as much as possible any portion of them from being wasted. The refuse of a cottager's house and garden, diligently pre-

served and well managed, would of itself be sufficient to keep his land in the highest state of fertility. As much land as would maintain a large family with all they require for their own consumption, so far from being impoverished with constant cropping, would become more fruitful every year until it reached the utmost state of productiveness of which the space is capable. The farmer who raises grain and breeds cattle for sale, yearly sends away a large quantity of the fertilizing matter, and is obliged to make up the deficiency by the purchase of foreign manure. With the cottager, however, this is not the case, for everything his land produces is consumed upon the spot, and may be returned to the soil in an altered form, as refuse or manure, with the addition of the fertilizing substances of the meat and fuel which he purchases. In order to make the most of everything for manure, he should have constantly an increasing mixen in the garden. This should be covered with a shed, with a floor formed of brick, stone, or sand and lime, and so contrived as to throw the drainage to one point, where a waterproof tank should be formed to receive it. The floor should be covered with a bed of peat a few inches deep, or with road-scrapings, marl, or the soil of the garden, if neither of the former can be obtained. To the place thus prepared should be daily conveyed every kind of refuse produced upon the premises, including that of the pig-sty and the privy, both of which, for greater convenience, should be contrived near at hand, and the daily addition of these materials should be covered with a thin layer of peat or earth, according to the quantity or offensiveness of the matter thrown

on. When the heap has accumulated to three or four feet deep, it may be thrown out of the shed to give place to a future store. The manure thrown out should be thoroughly turned and mixed, and receive another slight covering of earth; after a few weeks it should be again turned, when it will soon be ready to be carried to the land and dug in. It is very desirable that dry peat, or dry coal or peat ashes, should always be at hand to mix with the night soil previously to its removal to the heap, which will destroy its offensiveness and preserve it from being wasted when fermentation takes place in the heap. A little common salt and powdered gypsum sprinkled now and then upon the increasing mixen would be valuable additions to such a compost. During its formation, the heap should be constantly kept flat at the top, in order that the added materials whether fluid or solid should be evenly distributed over it. The drainings received by the tank mixed with more water will afford an excellent liquid manure to apply to growing plants by means of a watering-pot. If more of this liquid manure be desirable, it might be easily obtained by pouring water upon the heap to increase the drainings, but it must at the same time be considered that by such means the strength of the solid manure will be diminished in a corresponding degree.

A waste of any of the substances which sustain the growth of plants, is in the eye of reason equally censurable with the waste of food itself, and a wise economy will equally be directed to the preservation of one as the other; yet what reckless *waste* everywhere prevails of the most fertilizing *materials*! While the insufficiency of the produce

of the land renders the inhabitants of England dependent upon foreign nations for corn, our cities and towns are rendered unwholesome by the neglect and waste of the materials of fertility, which if properly preserved, as in the case of the cottagers above-mentioned, would ensure abundance and render foreign supplies needless, and perhaps afford a surplus of corn for exportation. Even in rural districts, the air is often rendered pestilential by a similar neglect, as is abundantly proved by the sanitary investigation at this time in progress. It is a startling fact announced by an eminent chemist, that by the right application of a pound of urine, a pound of wheat might be produced! What then must be the loss in a country containing many millions of inhabitants, when scarcely a thought is bestowed upon the preservation of night soil, "though by artificial means it might economically be rendered totally inoffensive, inodorous, and transportable."

PARING AND BURNING SOILS.

Much difference of opinion has long prevailed on the subject of paring and burning the surface of the soil, always owing to a want of proper discrimination as to the nature of the soils so treated. It is very injurious to pare and burn a sandy soil, which is already deficient in adhesive matter, and in many cases has rendered such a soil unproductive for years, and indeed effected a permanent injury for reasons that will presently appear; on such lands, therefore, it should never be practised. On clayey and adhesive soils, however, it may often be resorted to with the greatest advantage, and as

the best means of laying the foundation of a successful course of cropping.

This mode of preparation of the soil is chiefly beneficial at the first breaking up of the strong soils of commons or old pasture, or such as have for many years lain down in grass. On such land there will be a redundance of rough vegetable matter, which it is very difficult to reduce by the ordinary mechanical means so as to make it fit for the reception of a crop. By paring and burning the surface this excess of vegetable matter is very much reduced, while no loss will be sustained but that of carbon and the elements of water, which the atmosphere will amply supply in the succeeding crop if the soil be duly prepared for it: all the inorganic substances remain, and more are set at liberty by the burning of the clay. It has been before stated that burning of clay has a twofold chemical effect—namely, in liberating potash, and also in rendering it capable of absorbing gases, and especially ammonia, from the atmosphere; it also mechanically improves a stubborn soil by rendering it more open and pervious to the air and more easily cultivated. By paring and burning, therefore, the powers of the soil are placed at the disposal of the cultivator, which he may to a certain extent exhaust by severe and improvident cropping, if not restrained by considerations for the future, or by proper covenants. It is the abuse of the practice which constitutes the real objection to paring and burning strong and heavy soils; for under proper regulations it is an excellent commencement of a judicious course of husbandry, by which it will produce a present reward in the success of the first crop, and a lasting benefit in

the improved mechanical and chemical state of the soil and its consequent fertility. The case is very different with regard to light and sandy soils; these are always too open, and the destruction of what little clay they contain inflicts upon them an irreparable injury by rendering them incapable of retaining manure or moisture.

On proper soils paring and burning, succeeded by a regular alternation of corn and green crops, with the usual appliances of a proper share of manure, is perfectly compatible with the interest both of landlord and tenant.

IRRIGATION.

The practice of watering or flooding land is derived from the earliest times to which history extends. In India as well as in Egypt, the cradles of agriculture, the annual overflow of the great rivers the Ganges and the Nile, and the extraordinary effect produced by these inundations, early led the way to the artificial management of water by diverting it over land which it could not otherwise have reached. It was subsequently practised by the Jews, the Romans, and other civilised people, as recorded both in sacred and profane history. There can be little doubt that the Romans spread the practice over a large part of Europe, and introduced it with other rural arts into this country.

Water constitutes a considerable part of the [illegible] and is also the means by which all [illegible]ich nourish plants are [illegible] can only enter their [illegible] water. All the [illegible]rooks and rivers,

are charged with mineral, vegetable, and animal matter, especially after heavy rains and the melting of snow in times of inundation; and when they flow or are diverted over the surface of the land, they must bring with them a constant supply of nutritious matter. All waters contain common salt; and an illustrious chemist asserts that they also contain phosphate of lime, and if it has not been found, it is because it has not been sought for. The water which falls in rain and snow contains ammonia and carbonic acid; and in its passage over and through the soil, collects and carries with it all other substances capable of contributing to the nourishment of plants, whether it flows at once into streams and rivers, or sinks into the ground to re-appear in springs.

Spring waters are often highly nourishing to grasses, and especially when they are thrown out by marly beds. The springs which issue from beneath the chalk, as in Wiltshire and Berkshire, produce the finest water-meadows in England; which must be attributed to the water containing all the fertilizing substances contained in marl and a portion of the green sand, which has recently been discovered to be rich in phosphate of lime. The flooding or irrigation of meadows may therefore be considered as the application upon a large scale of liquid manure; the ingredients of which are mixed and furnished by nature, requiring no other labour than their careful distribution, by the most natural and simple means. Independent of the fertilizing substances contained in the waters, springs, brooks, and rivers, they appear to be beneficial in keeping up the temperature of the land during winter, and thus ensuring a very

early growth of the grass. On this subject we shall quote the following observations of Sir Humphry Davy: "In 1804, in the month of March, I examined the temperature in a water-meadow near Hungerford in Berkshire, by a delicate thermometer. The temperature of the air at seven in the morning was 29°; the water was frozen above the grass. The temperature of the soil below the water in which the roots of the grass were fixed was 43°." He goes on to state, "In general, those waters which breed the best fish are the best fitted for water-meadows; but most of the benefits of irrigation may be derived from any water. It is, however, a general principle, that waters containing impregnation of iron, although possessed of fertilizing effects when applied to calcareous soils, are injurious on soils that do not effervesce with acids; and that calcareous waters, which are known by the earthy deposit they afford when boiled, are of most use on siliceous soils, or others containing no remarkable quantity of carbonate of lime."

The air contained in all waters possesses a much larger proportion of oxygen than atmospheric air; which, no doubt, has a beneficial effect upon the roots of plants and the substances which surround them. In some parts of Wiltshire, the Vale of Pewsey, for instance, beds of peat of little or no value in the natural state have been converted into very fertile water-meadow, producing three successive crops of nourishing herbage; and the extensive range of water-meadow lately formed by the Duke of Portland in Nottinghamshire, is one of the most remarkable triumphs of economical skill in modern agriculture.

CHAPTER XIV.

THE EFFECT OF DIFFERENT MANURES ON THE QUALITY OF CORN CROPS —THE QUANTITY AND QUALITY OF CROPS AFFECTED BY THE TIME OF CUTTING—ROTATION OF CROPS; THE CAUSE OF THE NECESSITY OF IT EXPLAINED.

THE two principal nourishing substances of grain are starch and gluten. Wheat contains much more gluten than barley, rye, or oats, to which it owes its superiority as a bread-corn. The quantity of gluten, however, contained in each of these different kinds of grain is very variable, and is very much influenced by the kind of manure applied to them. The means of separating the gluten has been before mentioned, and also that the flour of wheat which contains the most gluten produces the best bread. The great variation in the quantity of gluten contained in different specimens of wheat will be shown in the following results of experiments upon different samples, English and foreign. These experiments were made chiefly by Chaptal, upon 100 parts, and the numbers express the quantity of gluten produced by each: 10, 11.95, 12.5, 17.3, 19.19, 21, 24, 26.7, 33.3, 35.1. The wheat of the south of Italy and that brought from the Ukraine in the south of Russia, afford always a large quantity of gluten, and are on that account used by the Italians for making macaroni and vermicelli.

The quantity of gluten in wheat and other grain is increased by the application of those animal manures which contain much salts of ammonia. Liebig found that 100 parts of wheat grown upon land manured with cow-dung produced 11.95 parts of gluten, whilst the same quantity grown on soil manured with human urine afforded 35.1, or nearly three times the quantity. The dung of the cow is very poor in ammonia, while its urine and that of all other animals yields a large quantity. Guano, a large part of which consists of salts of ammonia, is calculated to produce wheat very rich in gluten. Professor Johnson gives the following proportions of starch and gluten in wheat grown upon the same land differently manured—

MANURE.	STARCH.	GLUTEN.
Blood	41	34
Sheep dung	42	33
Horse dung	62	14
Cow dung	72	12
Vegetable manure . .	66	10

Barley and oats, which contain much less gluten than wheat at all times, are not equally affected by manures rich in ammonia. The lowest quantity of gluten contained in barley to which vegetable manure only had been applied, is 3½ per cent, and the highest in that manured with night-soil or blood is 6½ per cent. That barley which contains the most gluten is best adapted to the feeding of cattle and swine, but is rejected by the maltster and brewer, who prefer samples which afford the most starch, and consequently the most saccharine matter and spirit by malting and fermentation. The former are, therefore, called mealing samples, and are distinguishable by their appear-

ance, and generally sell for an inferior price to those which are adapted for malting. Those which contain the most gluten are generally coarser, yellow and thick skinned, while those which abound more in starch are short, white, and plump. The barley which is sometimes grown after wheat, (though a bad practice,) affords a better sample for the maltster than the more abundant crop which follows turnips fed off by sheep, by which the land is enriched with the urine of the flock. The most favourite malting samples are produced in Norfolk, where the land for the most part is naturally poor, but is made productive by very superior farming.

Manures which contain much ammonia have a powerful effect in promoting the growth of all plants, but especially those which serve for the food of men and animals, and which are rich in gluten, albumen, and caseine, substances identical in chemical composition, which serve for the production of blood, and the increase of flesh and other solid parts of the body. With the general increase of the plant, the starch and sugar—the other nourishing materials—also increase, and afford a larger quantity of nourishing matter of each; though, as we have seen, in the cases of grain, in different proportions.

ROTATION OF CROPS.

This subject is one that has much occupied the attention of farmers, who have long proved by experience that they could not obtain good crops of any kind of grain in successive years, and that after the land had produced a good crop of wheat, barley, or oats, for instance, an interval of rest was

required before it was capable of yielding a good return of the same kind. Before the cultivation of grain was understood, the land after having produced one crop of grain was generally suffered to remain for the next season without any kind of crop, during which it was called a fallow field, and underwent ploughing and working to fit it for the reception of seed; which, after a scanty manuring, was sown in the following autumn or spring. By this summer or naked fallowing operation much time was lost, and the crops produced were very inferior. The introduction of fallow or green crops effected a great change, by which it was found that the land would produce more bread-corn in a given number of years, when the intervals were occupied with turnips and pulse crops, or produced grass, clover, or tares, for the food of sheep and cattle.

The reason for the necessity of an interval between corn crops, and the advantage of intervening crops of another kind, is, that plants of different kinds require very different quantities as well as kinds of mineral food. Wheat, barley, and oats require much silicate of potash for their straw, as well as phosphates for their seed; and a succession of these crops soon exhausts the soil of such substances, though it would produce a crop of another kind whose requirements were different. A crop of turnips, clover, or tares, requires no silicates, and if used upon the spot as the food of sheep and cattle, only partially exhausts the phosphate of lime (bone earth). These intermediate crops afford time for a further disintegration of the soil for the production of silicates; while by their great quantity of leaves they draw a large

portion of nourishment from the air, and replenish it with humus and ammonia. Neither potatoes nor pulse crops (peas and beans) consume silicates; and land that would not afford a good white corn crop, is often rich in substances which the former crops require for their nourishment, and capable of producing them in abundance. By thus varying the crops, each particular kind finds a sufficiency of the mineral food it requires, which the previous crop had left as useless, while the intermediate green or fallow crops enrich the soil with a large accession of organic matter drawn from the atmosphere. The ploughing down of green crops, such as tares and clover, when in flower, by which no mineral substance of any kind is abstracted, is an excellent preparation of the land, especially for potatoes, which require much humus to produce them of good quality. Wheat is nurtured by the decaying roots of clover and grass that preceded it, while the rest the land has had from producing a white-straw crop has afforded time for the production of silicates, which are required for its straw and leaves. For the same reason, wheat succeeds well after peas and beans, which, while they require no silicates, enrich the soil by their plentiful system of leaves. Thus, by a judicious succession of crops, the land is enriched by the growth of green food for sheep and cattle, the manures applied are made the most of, and the season for a fresh supply delayed.

Whatever skill, however, may be exercised in adopting the best rotations, soils must be often deficient in one or more of the substances which form the mineral food of plants. All corn crops, as well as sheep and cattle, when sold, carry away

bone earth, which cannot therefore be returned in the ordinary course of manuring with the dung-cart; and this substance, which, though widely diffused, is never very abundant, is generally that which is most deficient, which accounts for its very beneficial effect when solely applied. Potash is a most likely substance to be exhausted, and also common salt and gypsum; and such deficiencies will perhaps most frequently occur in the order in which they have been mentioned. It is in such cases that these partial manures often prove beneficial when used in addition to the usual supply of farm-yard dung.

THE QUANTITY AND QUALITY OF CROPS AFFECTED BY THE TIME OF CUTTING.

The time of cutting hay and corn has a great influence upon their quantity, as well as their value as food. The starch, mucilage or gum, and sugar, so abundant in the grasses at the time of flowering, and which is so nourishing to sheep and cattle, from that time undergo a change, and by the time the seeds are perfected, are converted into woody fibre, which yields but little nourishment. The actual weight is also diminished; and at the same time the land is impoverished by the production of seeds, which are mostly lost before the hay is eaten, and can afford very little benefit to cattle. The straw of corn crops suffers a similar injury by standing a longer time than is needful for the perfection of the grain. When that part of the stalk of wheat immediately under the ear turns quite yellow, it indicates that no more juices are transmitted to the grain, which is then quite plump and

full; the starch, gluten, and albumen have become consolidated; and if the crop be cut at this time, the wheat will be thin skinned, and yield the largest quantity and best quality of flour, and the least bran. The various grasses produced by our meadow and pasture lands differ widely in their time of flowering, and, therefore, in the time at which they arrive at perfection for the purpose of making hay. The proper time of cutting will depend upon the blossoming of the most prevailing or abundant kinds, and must be determined by the observation of the farmer, so far as the weather will allow him to exercise a choice. Upwards of ninety different kinds are enumerated, some of which come into flower even as late as the latter end of August; but by far the most abundant and valuable produce their flowers from the middle of June to the middle of July, and perfect their seed in about sixteen or eighteen days. Though cattle, and particularly sheep, have the power of digesting some portion of the woody fibre, experience has proved that they both thrive better on hay cut in due season, when the grasses are most succulent and abundant, than when it has stood till the greater part of the seeds have ripened.

CHAPTER XV.

THE QUANTITY AND DIFFERENT KINDS OF NUTRITIVE MATTER AFFORDED BY DIFFERENT CROPS—THE PROCESS OF NOURISHMENT IN THE ANIMAL SYSTEM—THE FEEDING OF CATTLE—THE PROPERTIES OF MILK, AND THE MAKING OF CHEESE.

THE total quantity of food which any given quantity of land will produce, will depend upon the kind of crops grown upon it. The nourishing matter afforded by bread-corn consists of starch, gluten and albumen, sugar and gum.

Professor Johnson gives the following estimate of the production of an acre of land bearing the several crops mentioned.

Wheat	25 bushels, or	1,500	pounds.
Barley	38 ,,	2,000	,,
Oats	50 ,,	2.250	,,
Peas	15 ,,	1,000	,,
Beans	25 ,,	1,600	,,
Indian Corn . .	60 ,,	3,120	,,
Potatoes . . .	10 tons, or	22,400	,,
Turnips . . .	25 ,,	56,000	,,

The quantity of peas and beans here given as the produce of an acre is very low, and would generally be considered as a failure, especially the former. According to the same respectable authority, the weight of dry nourishing matter of different *kinds is stated* as follows:—

	STARCH.	GLUTEN AND ALBUMEN, OR CASEINE.	SUGAR AND GUM.	WOODY FIBRE.
Wheat	825	315	60	
Barley	1,200	120	160	
Oats	1,215	100	220	
Peas	240	260	20	
Beans	670	370		
Indian Corn	2,100	280	90	
Potatoes	2,688	224		1,253
Turnips	3,900	1,400	5,000	

In considering the above estimate of the produce of an acre of land under the several crops mentioned, it will appear that there is not only a wide difference in the total quantity of food produced by each, but also a great disproportion in the relative quantities of the different substances which each contains. All these substances are commonly regarded as nourishing matter; but, in order to form a just estimate of each crop as the food of man and inferior animals, it will be necessary to consider the part which they play in the nutritive process. It has been previously stated, that starch, sugar, and gum consist of nearly equal proportions of carbon and the elements of water, and that sugar differs from starch in its elementary composition only in containing rather more of the latter. Now, all animals which subsist on vegetable food consume a great quantity of starch, sugar, and their resembling substances, gum and mucilage; but little or none of these are found in their excrements, which consist of undigested woody fibre, salts, and water. How, then, have they been used up, and what has become of them? for the increase of the weight of the animal, if any, will not account for the large quantity consumed. *They* have indeed undergone combustion in the *body* of the animal; that is, the greater part of

their carbon and hydrogen have entered into combination with the oxygen of the air by means of the lungs and skin, and have been given out or expelled from the system in the form of carbonic acid gas and watery vapour, and their decomposition has served to furnish the heat which sustains the temperature of the body, while a small portion of these substances has been retained in the case of feeding animals for the production of fat. This part of the food of animals undergoes the same change as if it had been burnt in the fire, and produces the same quantity of heat, only in the former case the process is more gradual, and the heat is distributed over a greater space of time.* Considering the nature of the change which these substances undergo, and the purpose they serve in the animal economy, they have been called the *food of respiration,* to distinguish them from those other products of vegetable life which contain nitrogen, namely, gluten, albumen, and caseine, which serve other purposes before they are finally decomposed and expelled from the bodies of animals.

The last-mentioned substances, it has been before observed, are produced from their elements in the organs of plants, and are all identical in their chemical composition; or, to speak more particularly, they consist, for the most part, of the same elements as starch and sugar, with a less proportion of oxygen, and the important addition of nitrogen, phosphorus, and sulphur, and several mineral salts.

It is from this part of the food of animals that blood is formed, from which are secreted all the

* Liebig.

substances which form the solid parts and organic structure of the body. All these parts are however continually undergoing change; that is, they are removed, and are replaced by fresh supplies from the digestive organs, through the medium of the blood. The removed parts being conveyed by the blood to the liver, their carbon is there separated to form bile, and finally undergoes combustion in the circulation, while the kidneys remove the soluble salts in the urine, and the insoluble salts pass off with the undigested or unburnt matter in the solid excrements.

As gluten, albumen, and caseine are the only substances in the food capable of forming blood, and, consequently, of sustaining the strength and vigour of the body, they have been appropriately called the *food of nutrition,* as a distinction from those which merely support respiration. This view of the part performed by the different substances of vegetables used for food, affords an explanation of the value of different crops raised for the sustenance of animals. That crop which yields the greatest quantity of food, both for respiration and nourishment, will, of course, sustain the greatest number of animals, and produce the greatest quantity both of flesh and fat, which accounts for the immense advantage derived to agriculture from the cultivation of turnips, as well as other large-leaved and bulky-rooted plants of a similar kind. The above explanations enable us to understand why bread made from wheat flour is more strengthening than that from barley or oats; why the vigour and enduring strength of a horse is increased by a partial substitution of beans for oats; why cattle, sheep, and swine increase in

flesh faster when peas, beans, or barley meal are added to their food; why Indian corn or maize is less sustaining, weight for weight, than European grain; why the Irish peasants and poor agricultural labourers of England, who live upon potatoes, consume so large a quantity to maintain their required strength, and the Hindoo so much rice,—both of which kinds of food are very deficient in nitrogenous substances, which constitute the food of nutrition. The poor Irish supply the deficiency of their usual diet by the use of milk, which affords caseine, and the Hindoos by the use of peas.

The above analysis of peas shows that they contain more food of nutrition in proportion to starch than any other grain, and their consequent value as an article of food.

Baron Liebig mentions a practice of the miners of South America, which places in a strong light the effect of beans used as food for man in giving strength, which accords with our practice of feeding horses with them in this country. "The labourers in the mines of South America, whose daily labour (perhaps the most severe in the world) consists in carrying upon their backs a load of earth from 180 to 200 pounds from a depth of 450 feet, subsist only upon bread and beans. They would prefer to confine themselves to bread, but their masters have found that they cannot work so much, and they, therefore, compel them, like horses, to eat beans. Beans are proportionally much richer in bone-earth than bread."—*Darwin's Researches.*

ON THE FEEDING OF CATTLE AND OTHER ANIMALS.

All animals consume less food, both of respiration and nourishment, in a state of rest than when they labour, or take other exercise. By motion and exertion, the depth and frequency of breathing is increased, and, consequently, a larger portion of oxygen is taken in by the lungs, causing a more rapid waste of the food of respiration, and also of the substances of the muscles and other organs, both of which must be replaced by a corresponding increase of food. If this be not attended to, the strength of the animal diminishes in proportion to the exertion required, and it gradually sinks from exhaustion. On the contrary, in a state of rest, or nearly so, as when cattle are fed in a pasture or in stalls, the supply of food is greater than the waste, in which case the fleshy and muscular parts increase by the continual accumulation of nitrogenous matter conveyed by the blood, and the excess of the other part of the food, the starch, sugar, &c. above what is required for respiration, is converted into fat. Temperature has a great influence in the quantity of food required by animals. In a cold atmosphere, and especially in rainy and moist weather, a great quantity of heat is removed from the surface of the body; while, from the greater condensation of the air, more oxygen is supplied to the lungs, causing a greater consumption and consequently requiring an additional supply of *fuel*, or the food of respiration, to keep up a due degree of heat in the body. All needless exposure, therefore, of *cattle* in the winter season is very bad economy. In *Holland*, the cattle are not only kept in houses in

the winter months, where the greatest attention is paid to cleanliness, but when turned out in the spring, are clothed for some time, to prevent the effect of the cold fogs which prevail in that country. Those ingenious and economical people have no doubt discovered, that, by this provident care, they prevent disease and effect a saving of food.

The three principal requisites for economical stall-feeding are, 1, a moderate degree of temperature, about 60° Fahr.; 2, perfect repose; and 3, the utmost attention to cleanliness, both of the animals and the stalls. By careful attention to these maxims, it has been found, that with a given quantity and quality of food the greatest effect has been produced. It should be always borne in mind that temperature or warmth, to a certain extent, supplies the place of food in the case of all animals, as well as of man.

Sheep when favoured by shelter consume less food and sooner grow fat, of which the most convincing proofs have been afforded, and are recorded in the second part of the first volume of the "English Agricultural Journal." Mr. Walbanke Childers, M.P. selected forty sheep of equal size and weight. Twenty of these were fed in the usual way in the open field, and the other twenty in a rough shed; yet the latter, though they received a fifth less food than those in the open field, showed an increase of 20 stone more in the short space of four months. At Lord Ducie's experimental farm also, 100 sheep kept in the open fields from the 10th of October to 10th of March, each ate 24 lbs. daily of swedes; while another 100 having a covered shed and a yard to run into at pleasure, only ate 20 lbs. *each of* the same turnips; thus clearly

proving the saving of food to have been effected solely by protection from the weather, and that for fattening sheep the plan is excellent. In these cases there was no waste of flesh by a worrying sheep-dog, and no loss of heat by exposure to weather. All animals in a state of nature seek shelter on the approach of storms and inclement weather, which they are prevented from doing in our enclosed but exposed fields, a privation which is very injurious to them, or at least, which occasions the necessity of a greater quantity of food to keep up the temperature of the body, and which has therefore no effect in producing fat. The effect of exposure in lowering the temperature of the bodies of animals becomes the more striking when we consider the quantity of heat carried off from their skins by evaporation, and that the heat required to convert water into vapour is more than four times that which would raise the same quantity to the boiling point; or, to speak more precisely, according to Mr. Watt, water at the temperature of 50° Fahr. requires 972° of additional heat to convert it into vapour, which in the case of cattle and sheep is withdrawn from their bodies.

When animals are kept in a state of repose, and plentifully supplied with food containing much starch, sugar, &c., as in the case of stall-fed cattle, they receive more of these substances than the oxygen taken in by the lungs and the skin can consume, which is the cause of the production of fat. Starch, sugar, and gum consist of the same elements as fat, and only differ in the proportion of oxygen. When the breathing is diminished by repose, and the oxygen is insufficient to consume all the carbon and hydrogen of the food, a portion of it yields up

its oxygen and becomes fat, which is deposited in every part of the body, but chiefly in the cellular substance about the kidneys and beneath the skin. By diminishing the food, or by increasing the exercise, and consequently the breathing, by which a larger quantity of oxygen is taken into the lungs, the accumulated fat rapidly diminishes, and ultimately disappears. The fat so lost is not discharged in the excrements, its elements have undergone combustion by union with oxygen, and have been separated from the body in the form of carbonic acid and water, through the medium of the skin and lungs, as before explained in speaking of the food. Exertion and exposure waste both flesh and fat; repose and shelter increase both, and economise food.

Fowls kept in the dark and perfectly quiet, fatten much quicker than those which have light and exercise; and geese and turkies treated in the same manner have their livers much enlarged by an accumulation of fat. In some parts of the Continent it is customary to confine fowls so as to prevent their moving, in order to accelerate their fattening.

A pig fed upon peas and beans increases much in flesh, but when potatoes chiefly are given it, though it will become fat, it will be very deficient in flesh. By giving oil cake, or the meal of peas, beans, or barley to cattle and sheep, (all substances rich in nitrogenous matter, the *food of nutrition,*) we afford the means of increasing the flesh in a much greater degree than when they are fed exclusively upon the different kinds of green food, such as grass, clover, turnips, &c.

Wild animals seldom become fat, as their wants

or fears afford them sufficient exercise to prevent the accumulation of fat, which can only take place in any considerable degree in domesticated animals, through the means of that plentiful provision, rest, and protection afforded them by man. Those animals which subsist entirely on flesh, and are therefore called carnivorous, have firm and muscular limbs without the least appearance of fat, but when domestic animals of this kind, as in the instance of the dog and cat, are induced to forego their natural habits and live on vegetable food, which they obtain without exercise, they soon become fat and slothful.

THE CHEMICAL PROPERTIES OF MILK; PROCESSES OF THE DAIRY, AND CHEESE MAKING.

Milk, the provision of nature for the support of young animals during the first stage of their existence, while they are incapable of digesting coarse food or of providing for themselves, is the most perfect and delicious of all natural aliments; owing to which its name is used in the figurative language of Scripture as an emblem of the goodness and bounty of Divine Providence. Dr. Henry gives the following analysis of cow's milk. 100 parts of cow's milk contain:—

Cheese, or caseine and albumen	4.48
Butter	3.13
Sugar of milk, (lactine)	4.77
Salts and mucus	0.60
Water	87.02
	100.00

As young animals live for some time on milk *only*, and increase much in size during that period, *it must* be evident that it affords all the substances

necessary to supply the food both of *respiration* and *nutrition*, the butter and sugar affording the materials for the former, and the caseine, albumen, and salts the latter, or, in other words, the ingredients of the blood. The saline part consists of phosphate of lime, muriate of soda, potash, and other salts. The phosphate of lime is an admirable provision to supply the rapid growth of bone in the young animal. The quantity of the different substances stated in the above analysis varies very much in different cows, and is considerably influenced also by the kind of food which the cow receives, which gives the milk different degrees of richness and flavour. Healthy meadows afford the richest milk, but when cows are depastured in low, shady, and watery situations, the quality is inferior. In the stalls, carrots and parsnips enrich the milk without imparting any disagreeable flavour, and mangold wurtzel perhaps increases the quantity of sugar, but if given in excess, gives a very disagreeable pungent taste to the milk. Turnips and cabbage increase the quantity of milk, but often render it exceedingly offensive. A small quantity of crushed oats or barley meal, given with other food, very much improves the quality of the milk, and is considered an economical addition while milch cows are in the stalls. The principal constituents of milk are held together by a very feeble affinity, and readily separate. When new milk is suffered to stand, the butter, or oily matter, rises to the surface in the form of cream, and in about twenty-four hours the whole forms a thick mass, and may be separated with very little loss. The separation of the cream is accelerated by using shallow vessels, and thereby increasing the

surface, and the most favourable temperature for that purpose is about 50° to 55° Fahr. In Devonshire a peculiar method is adopted for the separation of the cream, which has a considerable effect on its consistence and flavour; after standing about twelve hours, the pan containing it is placed over a charcoal fire, which quickly causes the whole of the cream to rise, carrying with it the coagulated albumen, and perhaps some portion of the curd. The cream thus produced is very thick and clotty, and is easily formed into butter, even by merely stirring it with the hand. Butter when made in the usual way by churning, contains three peculiar volatile acids, the principal of which is called butyric acid, which imparts to it that particular and agreeable flavour for which fresh butter is remarkable, but is soon lost by keeping or salting. Fresh butter contains always some portion of curd, which soon causes it to become rancid; the curd may be separated by melting the butter in hot water; thus purified it keeps much longer, but has lost the agreeable flavour above mentioned. When new or skimmed milk is suffered to stand till it becomes sour, it coagulates, that is, the curd separates from the mass of fluid. The curd or caseine appears to be held in solution by means of the potash of the milk; the sourness is occasioned by a portion of the sugar, or lactine, being converted into lactic acid by putrefaction, and the acid thus formed unites with the potash, and thus renders the curd insoluble. Any acid mixed with the milk causes the same separation, and by the same action; but in the process of making cheese, a small portion of dried calves' maw, called rennet, is macerated in water some hours, which is then

mixed with the warm milk, and being well diffused through the mass, causes by its putrefactive action a rapid change of the sugar of milk into lactic acid, and the consequent precipitation of the curd. In order to explain this change more clearly, it must be recollected that animal substances, with the presence of moisture and the contact of air, are exceedingly prone to undergo putrefaction, of which the oxygen of the air is the exciting cause. This putrefaction is a state of change of the elements of the substance, which are undergoing new arrangements, and which action it is capable of communicating to similar substances in contact with it. Putrefying flesh or putrefying caseine also exerts an influence upon the sugar of milk (lactine), and causes a new arrangement of its elements, by which it is converted into lactic acid, or the acid of milk.

As soon as milk is drawn from the cow, and exposed to the air, a change in the curd commences; and this action being communicated to the sugar, gradually converts it into acid, producing the sourness of the milk, and causing the separation of the curd, by the union of the acid with the potash which kept the curd in solution, as above mentioned. Now, the calves' maw, or rennet, is animal matter in a state of such change, that is, a state of putrefaction; and when macerated in water, communicates to it particles of its substance undergoing that change; and the quantity, however small, is sufficient, when mixed with the milk, to inoculate, as it were, the mass of caseine, which, reacting upon the sugar in the way described, soon produces sufficient acid to separate or *precipitate* the curd. A very small

quantity of lactic acid, formed as above mentioned, is sufficient to saturate the potash of the milk, and separate the curd; but as the formation of the acid still proceeds, and the whole of the whey would soon turn sour, and produce injurious effects upon the curd, the latter must be quickly removed, and all the whey carefully separated from it by division and pressure.

When the fresh cheese, or curd, is carefully freed from the whey, and salted, it is a mixture of casein and butter with some of the salts of the milk. It is then put into vats, or wooden frames, of the size and depth of the required cheese, a linen cloth of open texture being first spread over the bottom and sides of the vat, and the ends drawn over the cheese. Several of these are placed upon one another, in the case of thin cheeses, under a powerful self-acting or lever press, where they remain for some days, according to the discretion of the manager; after which they are removed to the drying or ripening-room, which is a chamber fitted with shelves, and kept at a low and equable temperature. The cheeses are placed singly upon the shelves, and turned from time to time. During the progress of ripening, the cheese becomes firm, and considerable changes take place. The best made English cheese contracts no unpleasant flavour. The flavour of cheese is produced by the decomposition of the butter, and the liberation of the volatile acids before mentioned; and the different degrees of pungency depend upon the quantity of those acids present in the cheese. The very offensive odour of some cheeses is owing to the putrefaction of the curd, from bad management, and the production of a gas containing sulphur.

For the chief part of the chemical properties of milk and cheese, we are indebted to Baron Liebig's admirable "Letters on Chemistry," who concludes the subject in the following words:— "The principal conditions of the preparation of the superior kinds of cheese (other obvious circumstances being of course duly observed) are, a careful removal of the whey which holds the milk sugar in solution, and a low temperature during the maturation, or ripening of the cheese."

The difference of the flavour and odour of different kinds of cheese depends upon the methods employed in the manufacture, upon the state of the rennet when added to the milk, upon the addition of salt, and upon the condition of the atmosphere during the period of making. It must be admitted that the plants, and especially the aromatic plants, upon which the animals feed, exercise some influence upon the quality of the cheese. The quality of the Roquefort cheese, which is prepared from sheep's milk, and is very excellent, depends exclusively upon the places where the cheese is kept, after pressing, and during maturation. There are cellars communicating with mountain-grottoes and caverns, which are kept constantly cool, at about 41° or 42° Fahr., by currents of air from the clefts of the mountains. The value of these cellars or store-houses varies with the property of maintaining an equable and low temperature. Giron mentions, that a certain cellar, the construction of which had cost 480*l.*, was sold for 8,600*l.*, being found to retain a suitable temperature; a convincing proof of the importance attached to temperature, in the preparation of *these superior* cheeses."

The modes of making cheese in this country vary very much in different districts, which, together with the herbage upon which the animals feed, occasions the diversity in quality and flavour which prevails. As a purely practical art, cheese-making has been carried to a high degree of perfection in this country, as is evinced in the excellent quality of several kinds, particularly those of Cheshire, Gloucestershire, and Somerset. It is, however, more than probable, that the practice is yet susceptible of improvement, by the aid of science, by rendering the process more economical and certain, and less dependent upon personal individual skill, which now produces such different results in the same district, where all other conditions are precisely the same; that is, where the kind of cow, the herbage, and, consequently, the milk, are exactly of the same quality. The Swiss have economical methods of making cheese, well deserving the attention of the British dairyman, and some of which might be adopted with advantage in this country, (as in the instance above mentioned,) of ripening the cheese at a low and steady temperature; one obvious benefit of which is, that it prevents or checks fermentation, or rather the putrefactive action which is so injurious to mild and agreeable flavour. So low a temperature as that mentioned, cannot be obtained in this country; but much might be done to obtain a cool and dry atmosphere, by a well-constructed building, with thick walls, and a thatched roof projecting a great way over them, so as to defend them from the action of the sun. Very thick walls of mud, lined inside with bricks, would be preferable to stone; and the air might be kept of

the desirable degree of dryness, by means of lumps of lime placed in pans upon the floor, or by muriate of lime, both of which have a strong attraction for moisture. We beg to observe, that these hints are thrown out as suggestions to those who may think that they might improve their cheese by attention to circumstances which before they had overlooked.

Whatever may be thought of any attempt at improving the mode of ripening cheese in this country, cleanliness is still more important in the manufacturing portion of the dairy; and for this most of our English dairies are remarkable, and cannot be excelled. The utmost attention to this is indispensable, as the smallest quantity of milk remaining dispersed on the floor, or on the vessels used, for even a short time, especially in warm weather, undergoes a putrefactive action, which is soon communicated to other milk, in which it produces an irregular and very injurious effect, and therefore cannot be too strictly guarded against.

When milk is kept at a regular temperature of about 90° Fahr. it undergoes fermentation, by which the whole of the sugar is converted into alcohol, which may be separated by distillation. By this means the Tartars obtain an intoxicating liquor from mares' milk, which they call "coumis."

When the cream is removed from milk, the latter retains all its caseine, or curdy matter, which still makes a very nourishing, though less palatable cheese, called skimmed cheese. Stilton, and what is called cream cheese, is made by adding to the new milk a large quantity of cream taken from other milk, by which they are rendered so remarkably rich.

APPENDIX.

LETTER TO PH. PUSEY, ESQ. ON BURNT CLAY.

MY DEAR SIR,—I now send you, as you wished, a report of my experience in the use of burnt clay, which I have applied to land, more or less, for the last seventeen years.

For the first ten years, it was upon a heavy clay-land farm in Cambridgeshire, about two miles south of Caxton, on the Old North Road; and for the last seven years, on the land I occupy here, which is of better quality than the Cambridgeshire farm; but both on a strong clay subsoil, and requiring under-draining. In both cases, I have burnt all the borders, headlands, and grass-balks in the fields, which had been enclosed with straight quick fences about thirty years ago, but had yet been cultivated, as in the open field system, with high-backed lands, ploughed in a serpentine direction, having in every field a great deal of waste-land, as above described. This has not only furnished excellent materials for burning, but also a supply of turf for draining, which, cut in the wedge form, is one of the cheapest and best modes of performing that necessary operation, without which the profitable occupation of heavy land cannot be carried on.

The work of burning is begun in May, and continued through the summer, in heaps containing from 50 to 100 yards each, at an expense of 6*d.* or 7*d.* per yard, which includes everything, except a few roots and brush-faggots, the quantity of which varies, according to the supply of turf. The average value of the wood consumed is about

10*s*. for every hundred yards of ashes. The great art is to let the clay burn slowly, which depends very much upon the proper formation of the walls, which are of turf, as the ashes then turn out black for the most part, and are considered much better than when they are red and clinking, like bricks. The more turf and vegetable matter, the better, (as weeds, scouring of ditches, and rubbish of every kind); but if sufficient turf can be raised to form the walls of the clamps, we find that, with the assistance of a few more roots or faggots, a great deal of clay, with very little of any vegetable matter, can be reduced to ashes. The fires require watching at night, as well as in the day-time, that they may not go out; and the clay always burns best that has been dug a week or two before clamping.

I have invariably found the application of burnt earth attended with beneficial effects, though I have not made any experiments by which to ascertain the exact amount of advantage. Where ashes have been used, the land works much more freely for several years, is sooner dry, and the produce is considerably increased. Upon both farms I have succeeded in raising the produce of wheat nearly ten bushels per acre, and other crops in proportion. The average used to vary from fifteen to twenty-five bushels per acre, now from twenty-five to thirty bushels; and I have found burnt clay one of the most useful auxiliaries in producing this result.

I have, also, found ashes very useful upon heavy grass-land, greatly improving the quality of the herbage, and enabling me to keep more stock. Upon one field in particular, which had been badly laid down, the quality of the herbage has been so much improved by the application of burnt earth, that I have determined to let it remain in grass, instead of breaking it up, as I had before intended.

The quantity used on strong arable land varies from forty to fifty yards per acre; on wood-land arable thirty yards is sufficient; on grass land from twenty to twenty-five yards. For grass land I sometimes mix the ashes with unburnt earth, lime, and a small quantity of yard manure, to form compost heaps.

The ashes are generally carted on in a dry time, as soon as convenient after harvest, and put upon clover-leys, bean or tare stubbles, or fallows, either for wheat, barley, or oats, as the case may be; and I have occasionally used

them upon young seeds. I consider the effect lasts seven or eight years, when, if a supply can be provided, they may very safely be repeated.

Very truly yours, F. PIM.

The Hazells, Baldock.

Having been allowed by Mr. Pim to inspect his heaps of burnt clay at the Hazells, I found that many of them contained so much lime as to deserve the name of marl. There was one heap of mere clay; but as it was burnt in a fresh situation, it did not appear quite clearly that this clay had ever been successfully applied to land. This practice, which was recommended by General Beatson, and of which Mr. Pim has given so satisfactory an account, still continues in many districts on a limited scale. I have obtained the following account of it from a correspondent in another county:—

"Having been requested to communicate with you on the subject of clay-burning, I am happy to do it as far as my knowledge extends. My attention was first called to it above twenty years ago, at a Bedford Agricultural Meeting, where the subject was discussed; and I heard it declared by some farmers then present, that they could not cultivate to any profit their strongest and worst lands but by the help of clay-burning. And a friend of mine afterwards, on the Buckinghamshire side of that county, confirmed the same statement. Consequently, being obliged to take into my own hands an impoverished strong-land farm here in Leicestershire, I resorted to the same experiment; and, encouraged by me, some of my neighbours did the same, and we all found the benefit of it.

"By clay-burning, we do not of course mean paring and burning, in which there can be little or no clay, and of which the ashes are expected to operate as a manure by means of the vegetable alkali in them; but we mean taking the inert mass at any depth below the first seven inches of the surface, such as the contents of newly-made pits, the bottoms of ditches made deeper than before, and the outcasts of sloughs. In this there can be very little of a feeding or fertilizing quality, though I cannot but think that a red or blue clay is of more value than a dirty white, and I have no doubt that stiff chalks or clayey stone brash, after the action of fire, would be much of the same quality. The most waxy clay lands well dressed over with burnt clay, not only become lighter and milder, as by the action

of lime, for the time, but so they continue for several years. A neighbouring farmer tells me that a field that he dressed in this way seven years ago has ploughed easier by a horse-draught, and *has been like different land*, ever since. Whereas lime, especially if caustic, when once saturated with rain, makes the land clôser and colder than ever. Strong land, on which barley is never a full and always a hazardous crop, fallowed and dressed over with burnt clay, and seeded down with barley in the spring, never fails to give a very good crop, and to be well covered with clover for the next year. In clay-burning, however, there is great skill and management required. Indeed, I know of no part of husbandry that does require so much good-sense, joined with experience in the burning. And upon this all depends. If it be well done, it is of great benefit to the farmer; if ill, it is quite the reverse.

" A nobleman in this neighbourhood made a large pond in the solid clay, and burnt all the outcast (there must have been between 2,000 and 3,000 loads); and he top-dressed the worst part of his parks with the ashes, falsely so called. And in three years afterwards they were above half carried off again, in the substance though not in the shape of brick-ends, to make foundation for roads. The heat should be always slow and steady, never, if possible, burning the clay red, but black; though this is very difficult indeed to manage, depending very much on the wind; and it is best effected by making heaps of about sixty or a hundred loads in each, and these will take from two to three months to burn. All inexperienced hands use too much fuel, get their fires too fierce, lay their stuff too hollow, make a great deal of smoke, (whereas, the less they make, the better,) get their heaps to a red heat, and burn them through in a week or ten days; and the consequence is, that when the heaps are opened, instead of ashes, or lumps that will fall, by exposure, into ashes, out roll knobs as hard and useless as brick-ends. Much also depends on the size of the clay lumps and their state of humidity: if too dry, they will burn too fiercely, and if too wet, they will not burn at all. And again, there is a great deal in the management of the fire, which we make of refuse coals from the pits. You, I expect, would use faggot wood, and that would simplify the process.

" If you have a quantity of clay land and fuel cheap, I have no doubt you will find the benefit of the clay-burning

system; but have it well done, or do not make the attempt. As general observations, nothing more occurs to me than to add, that these ashes should be laid on thick, chiefly on fallows, and at the rate of forty cart loads, or nearly, to the acre."

"The specimens of the earth used in this case are some of them marl and some clay. Altogether, it does not appear quite clearly, that clay without lime can be used for this purpose; particularly as it is more likely to burn into hard lumps than marl. But our cold clay lands are so much in want of any substance which would open them, that the process appears to deserve a trial, even when they are found not to contain any lime."—PH. PUSEY.

The general methods of proceeding to work is, to make an oblong enclosure of the dimensions of a small house, (say fifteen by ten feet,) of green turf sods, raised to the height of three and a half feet to four feet. In the inside of this enclosure, air-pipes are drawn diagonally, which communicate with the holes left at each corner of the exterior wall. These pipes are formed of sods put on edge, and the space between them only so wide as another sod will easily cover. In each of the four spaces left between the air-pipes and the outer wall, a fire is kindled with wood and dry turf, and then the whole of the inside of the enclosure or kiln is filled with dry turf, which is very soon on fire; and on the top of that when well kindled is thrown the clay, in small quantities at a time, and repeated as often as necessary; which must be regulated by the intensity of the burning. The air-pipes are of use only at first, because, if the fire burns with tolerable keenness, the sods forming the pipes will soon be reduced to ashes. The pipe on the weather side of the kiln only is left open, the mouths of the other three being stopped up, and not opened except the wind should veer about. As the inside of the enclosure or kiln begins to fill up with clay, the outer wall must be raised in height, always taking care to have it at least fifteen inches higher than the top of the clay, for the purpose of keeping the wind from acting on the fire. When the fire burns through the outer wall, which it often does, and particularly when the top is overloaded with clay, the breach must be stopped up immediately, which can only be effectually done by building another sod wall from the foundation and opposite to it;

and the sods that formed that part of the first wall are soon reduced to ashes. The wall can be raised as high as is convenient to throw in the clay; and the kiln may be increased to any size by forming a new wall when the previous one is burnt through. I have seen them so wide as to afford a space for a horse and cart to turn upon them; but when they are so broad, it requires the workmen to walk on the top of them when feeding with clay, which I would not recommend, because the more loosely the clay can be laid on, the more rapidly it will burn. I did not take all the trouble above-stated with my kilns, having the advantage of a quantity of old moss (peat), sticks and tree roots, which I split, and kindled a large parcel of them, and surrounded the fire with a quantity of dry turf; and as soon as it was kindled I built round a strong wall of sods, and went on adding clay to the fire and sods to the outer walls when necessary, till the kilns are so large as to contain upwards of a hundred loads of ashes. The principal secret in burning, consists in having the outer wall made quite close and impervious to the external air, and taking care to have the top always lightly, but completely, covered with clay; because if the external air should come in contact with the fire, either on the top of the kiln, or by means of bursting through the sides, the fire will be very soon extinguished. In short, the kilns require to be attended nearly as closely as charcoal pits. Clay is much easier burnt than either moss or loam. It does not undergo any alteration in its shape, and on that account allows the fire and smoke to get up easily between the lumps; whereas moss and loam, by crumbling down, are very apt to smother the fire, unless carefully attended to. No rule can be laid down for regulating the size of the lumps of clay thrown on the kiln, as that must depend on the state of the fire; but I have found every lump completely burnt on opening the kiln, and some of them were thrown in larger than my head. Clay, no doubt, burns more regularly if it be dug up and dried for a day or two before it be thrown on the kiln; but this operation is not necessary, as it will burn though thrown on quite wet. After a kiln is fairly set a-going, no coal or wood or any sort of combustible is necessary; and it can only be extinguished by inattention or carelessness of the operator, the vicissitudes of the weather having hardly any effect on the fires if properly

attended. It may, perhaps, be necessary to mention, that when the kiln is burning with great keenness, a stranger to the operation may be apt to think that the fire is extinguished. If, therefore, any person, either through impatience, or a too great curiosity, should insist on looking into the interior of the kiln, he will certainly retard, and may possibly extinguish the fire; for, as I mentioned before, the chief secret consists in keeping out the external air from the fire."

These directions are sufficiently particular to enable any person of tolerable skill to burn clay with success. There are many situations where this practice is most likely to prove of the greatest advantage, especially on those clay soils which in their natural state are of such difficult cultivation, and amongst others the clays of the coal measures. Whether the clay contain carbonate of lime or not, the burnt clay must prove a great mechanical improver of the soil, as well as chemically beneficial. To such clay, however, limestone or chalk in favourable situations might be added, and burnt in regular kilns. But the districts, unquestionably, that would derive the greatest benefit from the application of burnt earth, are those that abound in marl and marly clays, such as the blue lias and inferior oolite, which are rich in carbonate of lime, and contain other important fertilizing elements. When marly clays are burnt, the carbonate of lime decomposes the silicates of the clay, and liberates their potash, which is the principal cause of the observed superiority of such clays.

DR. URE'S OBSERVATIONS ON GUANO.

Messrs. Anthony Gibbs & Co. of 47, Lime-street, London, being largely engaged, as agents of the Peruvian and Bolivian governments, in the recent introduction into Europe, from the west coast of America, of the manure guano, have deemed it advisable to give to agriculturists as much defined and authentic information in regard to its constitution and merits as its recent introduction will permit. A certain quantity of inferior guano having been introduced into this country, it is natural to conclude that the few failures attending experiments made with this manure, have arisen from the use of the inferior article.

The importers of the Peruvian and Bolivian guano, commissioned for the sale of it by the governments of these

countries, to whom the deposits of this manure belong, have therefore thought it well for the satisfaction of consumers to submit samples of their different cargoes to Dr. Andrew Ure, a gentleman well known in the scientific world for his chemical knowledge, who, after many elaborate experiments on the subject, has drawn up the following general report and analysis :—

" London, 43, Charlotte-street, Bedford-square,
13th February, 1843.

" In these various analyses, performed with the utmost care, and with the aid of the most complete apparatus for both inorganic and organic chemical research, attention has been directed not only to the constituents of the guano which act as immediate manure, but to those which are admitted by practical farmers to impart durable fertility to the ground. The admirable researches of Professor Liebig have demonstrated that azote (nitrogen), the indispensable element of the nutrition of plants, and especially of wheat and others abounding in gluten, must be presented to them in the state of ammonia; yet not altogether in a pure or saline form, for as such it is too readily evaporated or washed away, but in the dormant, or as one may say, the *potential* condition, in contradistinction from the actual. Genuine Peruvian and Bolivian guano, like that which I have minutely analysed for Messrs. Anthony Gibbs & Sons of London, and Messrs. W. J. Myers & Co. of Liverpool, the two authorised agents for its sale, surpasses very far all other kinds of manure, whether natural or artificial, in the quantity of *potential* ammonia which it contains, and therefore in the permanency of its action upon the roots of plants; while, in consequence of its ample store of ready formed ammonia, it can give immediate vigour to vegetation.

" Urate of ammonia constitutes a considerable portion of the azotized organic matter of well-preserved guano; it is nearly insoluble in water, is not volatile, and is capable of yielding to the soil, by its slow decomposition, nearly one-third of its weight of ammonia. No other manure can rival this animal saline compound. One of the said samples of guano afforded, on analysis, not less than 17 per cent. of potential ammonia, besides 4½ per cent. of the actual or *ready* formed ammonia; other samples from 7 to 8 per cent. of ammonia in each of these respective states.

" The genuine guanos, of which I have just spoken, are the

mere excrements of birds, and are free from the sand, earth, or clay, and common salt reported in the analyses of some guanos. Indeed, I myself have found 30 per cent. of sand with almost no ammonia in an effete guano imported into England. The Peruvian and Bolivian guanos contain moreover from 20 to 30 per cent. of phosphate of lime, the same substance as bone-dust; but elaborated by the birds into a pulpy consistency, which, when it becomes soluble in water, is readily absorbable by the roots of plants, and digestable, so to speak, in their organs.

"I feel, therefore, well warranted to affirm, that by the judicious application of these genuine guanos, mixed with twice or thrice their weight of marly or *mild* calcareous earth to convert the soluble phosphate of ammonia into bone-earth, especially where they contain much ready formed ammonia, such crops will be produced, even upon sterile lands, as the farmer has never raised upon the most improved soil with ordinary manure. To the West India planter the guano will prove the greatest boon, since it condenses in a portable and inoffensive shape the means of restoring fertility to his exhausted cane-fields, just as it has long enriched the poor lands of Peru."

Dr. Ure gives the following analysis of a Peruvian guano reported as possessing the greatest fertilizing power.

Matter soluble in water, 47 per cent., consisting of—

Sulphate of potash, with a little sulphate of soda	6.00
Muriate of ammonia	3.00
Phosphate of ammonia	14.32
Carbonate of ammonia	1.00
Sulphate of ammonia	2.00
Oxalate of ammonia	3.23
Water	8.50
Soluble organic matter and urea	8.95
	47.00

Matter insoluble in water, 53 per cent., consisting of—

Silica	1.25
Undefined organic matter	9.52
Urate of ammonia	14.73
Oxalate of lime	1.00
Sub-phosphate of lime	22.00
Phosphate of magnesia and ammonia	4.50
	53.00

ON A MODE OF MANURING VINES.

The following very interesting particulars are extracted from Baron Liebig's admirable work upon Chemistry in its application to Agriculture and Physiology, which he introduces with these remarks:—

"The observations contained in the following pages should be extensively known, because they furnish a remarkable proof of the principles which have been stated in the preceding part of the work, both as to the manner in which manure acts, and on the origin of the carbon and nitrogen of plants.

"They prove that a vineyard may be retained in fertility without the application of animal matters, when the leaves and branches of vines are cut into small pieces and used as manure.

"According to the first of the following statements, both of which merit complete confidence, the perfect fruitfulness of a vineyard has been maintained in this manner for eight years. Now, during this long period, no carbon was conveyed to the soil, for that contained in the pruned branches was the produce of the plant itself, so that the vines were placed exactly in the same condition as trees in a forest, which receive no manure. Under ordinary circumstances a manure containing potash must be used, otherwise the fertility of the soil will decrease. This is done in all wine countries, so that potash to a very considerable amount must be extracted from the soil.

"When, however, the method of manuring now to be described is adopted, the quantity of alkalies exported in the wine, does not exceed that which the progressive disintegration of the soil every year renders capable of being absorbed by the plants.

"On the Rhine, one litre of wine (about 1¾ pints English) is calculated as the yearly produce of one metre of land, (about 10¾ feet English). Now, if we suppose that the wine is three-fourths saturated with cream of tartar (tartrate of potash), a proportion much above the truth, then we remove from every square metre of the land with the wine, only about 28 grains of potash.

"One vine stock, on an average, grows on every square metre of land, and 1000 parts of pruned branches contain 56 to 60 parts of carbonate, or 38 to 40 parts of pure potash, and 45 grammes (about 1½ ounces English) contain

as much potash as one litre of wine. But from ten to twenty times this quantity of branches is yearly taken from the abôve extent of surface."

On the Manuring of the Soil in Vineyards.

"In reference to an article in your Paper—No. 7, 1838, and No. 29, 1839,—I cannot lose the opportunity of again calling the public attention to the fact, that nothing more is necessary for the manure of a vineyard than the branches which are cut from the vines themselves.

"My vineyard has been manured in this way for eight years, without receiving any other kind of manure, and yet more beautiful and richly-laden vines could scarcely be pointed out. I formerly followed the method usually practised in this district, and was obliged, in consequence, to purchase manure to a great amount. This is now entirely saved, and my land is now in excellent condition."

"When I see the fatiguing labour used in manuring vineyards—horses and men toiling up the mountains with unnecessary materials—I feel inclined to say to all, come to my vineyard and see how a bountiful Creator has provided that vines shall manure themselves, like the trees in a forest, and even better than they! The foliage falls from trees in a forest only when they are withered, and they lie for years before they decay; but the branches are pruned from a vine in the end of July or beginning of August, whilst still fresh and moist. If they are then cut in small pieces and mixed with the earth, they undergo putrefaction so completely, that, as I have learned by experience, at the end of four weeks not the smallest trace of them can be found." *

The following notices of the same fact are from another vine grower:—

"The best manure for vines are the branches pruned from the vines themselves, cut into small pieces and immediately mixed with soil.

"These branches were used fôr manure long since in the Bergstrasse. Mr. Frauenfelder says, 'I remember that, twenty years ago, a man called Peter Muller had a vineyard which he manured with the branches pruned from the vines. His way of applying them was to hoe them into the soil after having cut them into small pieces.

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* Slightly abridged from an Article from Mr. Kerbs of Seekeim.

"'His vineyards were always in a thriving condition; so much so, indeed, that the peasants here speak of it to this day, wondering that old Muller had so good a vineyard, and yet used no manure."

Lastly, Wilhelm Ruf, of Schriesheim, writes:—

"For the last ten years I have been unable to place dung on my vineyard, because I am poor and can buy none. But I was very unwilling to allow my vines to decay, as they are my only source of support in my old age; and I often walked very anxiously among them, without knowing what I should do. At last my necessities became greater, which made me more attentive, so that I remarked that the grass was longer on some spots, where the branches of the vines fell, than on those on which there was none. So I thought upon the matter, and then said to myself, if these branches can make the grass large, strong, and green, they must also be able to make my plants grow better, and become strong and green. I dug, therefore, my vineyard as deep as if I would put dung in it, and cut the branches in pieces, placing them in the holes, and covering them with earth. In a year I had the very great satisfaction to see my barren vineyard become quite beautiful. This plan I continued every year, and now my vines grow splendidly, and remain the whole of the summer green, even in the greatest heat.

"All my neighbours wonder very much how my vineyard is so rich, and that I obtain so many grapes from it, and yet they all know that I have put no dung upon it for ten years."

SEA-WEED.

The productive power of sea-water, in multiplying and sustaining plants and animals, receives a very striking illustration from the following passage in Darwin's "Journal of the Voyage of the Beagle in the South Seas."

"There is one marine production which, from its importance, is worthy of a particular history. It is the Kelp, or Fucus giganteus of Solander. This plant grows on every rock, from low-water mark to a great depth, both on the outer coast and within the channels. I believe, during the voyage of the Adventure and the Beagle, not one rock near the surface was discovered which was not buoyed by this floating weed. The good service it thus affords to

vessels navigating near the stormy land is evident, and it has certainly saved many a one from being wrecked.

"I know few things more surprising than to see this plant growing and flourishing amidst those great breakers in the Western Ocean, which no mass of rock, be it ever so hard, can long resist. The stem is round, slimy, and smooth, and seldom has a diameter of so much as an inch. A few taken together are sufficiently strong to support the weight of the large loose stones to which, in the inland channel, they grow attached; and some of these stones are so heavy that, when drawn to the surface, they can scarcely be lifted into the boat by a single person.

"Captain Cook, in his voyage, says. that at Kerguelen's Land, 'some of this weed is of a most enormous length, though the stem is not much thicker than a man's thumb. I have mentioned that upon some of the shoals upon which it grows, we did not strike ground with a line of twenty-four fathoms; the depth of water therefore must have been greater. And as this weed does not grow in a perpendicular direction, but makes a very acute angle with the bottom, and much of it afterwards spreads many fathoms on the surface of the sea, I am well warranted to say that some of it grows to the length of sixty fathoms and upwards.' Certainly, at the Falkland Islands, and about Terra del Fuego, extensive beds frequently spring up from ten and fifteen fathoms water. I do not suppose that any other plant attains so great a length as 360 feet, as stated by Captain Cook. The geographical range is very considerable; it is found from the extreme southern islets, near Cape Horn, as far north on the eastern coast (according to the information given by Mr. Stokes) as latitude 43°, and on the western it was tolerably abundant, but far from luxuriant, at Chiloe, in latitude 42°. It may possibly extend a little further northward, but is soon succeeded by a different species. We thus have a range of 15° of latitude, and, as Cook (who must have been well acquainted with the species) found it at Kerguelen's Land, not less than 140° in longitude."

"The number of living creatures of all orders, whose existence depends on that of the kelp, is wonderful. A great volume might be written describing the inhabitants of one of these beds of sea-weeds. Almost every leaf, excepting *those which float* upon the surface, is so thickly in-

crusted with corallines as to be of a white colour. We find exquisitely delicate structures, some inhabited by simple hydra-like polypi, others by more organized kinds, and beautiful compound ascidiæ. On the flat surfaces of the leaves, various patelliform shells, Trochi, uncovered molluscs, and some bivalves are attached. Innumerable Crustacea frequent every part of the plant. On shaking the great entangled roots, a pile of small fish, shells, cuttle-fish, crabs of all orders, sea-eggs, star-fish, beautiful Holuthuriæ, and other crawling animals, all fall out together.

"I can only compare these great aquatic forests of the southern hemisphere with the terrestrial ones in the inter-tropical regions. Yet, if the latter should be destroyed in any country, I do not believe nearly so many species of animals would perish, as, under similar circumstances, would happen with the kelp. Amidst the leaves of this plant, numerous species of fish live, which no where else could find food or shelter; with their destruction, the many cormorants, divers, and other fishing birds, the otters, seals, and porpoises, would soon perish also; and, lastly, the Fuegian savage, the miserable lord of this miserable land, would redouble his cannibal feast, decrease in numbers, and perhaps cease to exist."

POTATO DISEASE.

Method proposed by Dr. Klotzsch for the protection of the potato plant against diseases.

The potato, which is an annual plant, represents in the tubers developed from the stem the perennial part of a plant. For while the duration of its development is analogous to that of animals, its functions coincide exactly with those of shrubs and trees.

The potato plant differs from all other plants which are cultivated for economical purposes in Europe, and can only be compared with the orchideous plants which yield salep, and which are not yet cultivated among us.

The tubers, both of the potato and of the salep plants are nutritious, and agree in this, that in the cells of the tubers grains of starch, with more or less azotized mucilage, are collected, while the cell walls possess the remarkable property of swelling up into a jelly, and thus becoming easily digestible when boiled in water.

But while the tuber of salep contains only one bud, or

germ, the potato usually developes several, often many germs.

The potato plant, like all annuals, exerts its chief efforts in developing flowers and fruit. Like all annuals, too, it has the power of shortening this period of development, when the power of the roots is limited; as also of lengthening it, when the extent and power of the roots are increased.

We observe in nature, that plants with feebly developed roots often have a weak, sickly aspect, but yet come to maturity in flower and fruit sooner than stronger individuals, well furnished with roots.

In perennial plants we observe a second effort, which is directed towards the preparing and storing up nutritious matter, for the consumption of the plant. The preparation of this nutriment is effected by the organic action of the leaves, under the influence of the roots: the stronger and larger the former are, the more is this preparation delayed.

The nutritious matters are stored in the coloured stratum of the bark in shrubs and trees, and in the tubers in the potato and salep plants. Not only, however, the nutrient matter, but also the cells, owe their action to the physiological action of the leaves.

On considering these things, it follows, that the potato plant requires more care than is usually devoted to it. Hitherto the whole cultivation consisted in clearing off weeds, and hoeing up the earth round the stems. Both of these measures are indeed necessary, but they are not alone sufficient; for the plant is cultivated, not on account of its fruit, but for the sake of its tubers, and our treatment should be modified accordingly.

The chief points to be attended to, with a view to the attainment of the object, namely, the increase of tubers, are—

1. To increase the power in the roots, and
2. To check the transformation which occurs in the leaf.

We attain both these ends simultaneously, if, in the 5th 6th and 7th weeks after setting the tubers, and in the 4th and 5th weeks of planting out germs furnished with roots, or at a time when the plants reach the height of six or nine inches above the soil, we pinch off the extreme points of the branches or twigs, to the extent of half an inch down-

wards, and repeat this on every branch or twig in the 10th and 11th weeks, no matter at what time of day.

The consequences of this check to the development of the stem and branches, is a stimulus to the nutrient matters in the plant, in the direction both of the roots, and the multiplication of the branches above the ground, which not only favours the power of the root, but also strengthens the roots and stalks to such a degree, that the matters prepared by the action of these parts are increased, and applied to the formation of tubers, while at the same time the direct action of the sun's rays on the soil is prevented by the thick foliage, and thus the drying up of the soil and its injurious consequences are avoided.

The checking of the transformation in the leaf is equivalent to the interruption to the natural changes of the leaves into the parts of the flowers, which is effected at the expense of the nutrient matter collected in the plant; and these, when this modification of the leaves is arrested, are turned to account in the formation of tubers.

Led by these views, I made in 1846 experiments on single potato plants, carefully marked, by pinching off the ends of the branches. They were so readily distinguished in their subsequent growth from the plants beside them, by more numerous branches, larger and thicker foliage, that in truth no marking was necessary.

The produce of tubers of these plants was abundant, and the tubers were perfectly healthy; while the plants next them, which had not been so treated, gave uniformly a less produce; at the same time, the tubers were rough on the surface, and in many instances attacked with the prevailing disease. This experiment was incomplete, and did not give a positive result, but it was yet encouraging to me.

In the middle of April, 1847, an experiment was made on a low-lying field with the round white potatoes generally cultivated here, a variety which had not suffered much from the disease which first appeared here in 1845. The potatoes were planted in the usual way by an experienced farm servant.

After weeding them in the end of May, I renewed my experiment by pinching off the points of the branches of every second row, and repeated this in the end of June. The result surpassed all expectations. The stalks of the plants not treated on my plan were long, straggling, and

sparingly furnished with leaves, the leaves themselves small and pale green.

In the next field, potatoes of the same variety were planted on the same day, and left to nature. They appeared in the first six weeks healthy, even strong, but gradually acquired a poor aspect as the time of flowering and fruit approached, and finally exhibited precisely the same appearances as the rows not treated by pinching off the extremities in the field on which my experiments were made.

The harvest began in the surrounding fields in the middle of August, and was very middling. The tubers were throughout smaller than usual, very scabby, and within these fields, to a small extent, attacked with the wet rot.

In the end of August, the difference between the rows treated by me and those not treated became so striking, that it astonished all the work people in the neighbourhood, who were never tired of inquiring the cause. The stalks of the rows left to themselves were all now partly dried, partly dead. On the contrary, the rows treated as above were luxuriant and in full vigour, the plants bushy, the foliage thick, the leaves large and dark green, so that most people supposed they had been later planted.

But the difference in the tubers was also very decided. The tubers in the rows treated on my plan were not indeed larger, but vastly more numerous, and they were neither scabby, nor infected with any disease whatever. A few had pushed, (which was ascribed to a late rain,) and were apparently incompletely developed, while scab and wet rot attacked more and more the tubers of the other plants, which also fell off on the slightest handling.

Although I am far from believing that I am able to explain the nature of the potato disease which has visited us of late years, yet I feel certain that I have discovered a means of strengthening the potato plant to such a degree as to enable it to resist the influences which determine such diseases.

Should any one be deterred from continuing the cultivation of potatoes, on account of the manipulation here recommended, which may be performed by women and even children, I would remind him that the same field planted with potatoes is capable of supplying food to twice as many persons as when employed to grow wheat.

From the Annals of Agriculture in Prussia, edited by the College of Rural Economy.

Dr. Klotzsch presented to the King of Prussia a memorial, offering to give the world his method of preventing disease in potatoes, provided he were assured of a remunetion of 2,000 dollars, (about 300*l.*) if after three years' experience it should be found advantageous.

The King handed the memorial to the Minister of the Interior, who requested the College of Rural Economy to discuss the matter with Dr. Klotzsch.

The president of the College undertook the arrangement, and after Dr. Klotzsch had explained to him privately his method, reported most favourably of it to the College, which unanimously recommended that the very moderate remuneration asked for by Dr. Klotzsch should be secured to him on the following conditions, which were accepted by him:

1. That the College of Rural Economy should be the judges of the efficacy of the proposed method.
2. That their decision should be given, at latest, within three years, provided the potato disease, against which the plants are to be protected, should appear during that period.

The Minister of the Interior approved of the recommendation, and authorized the College to conclude an agreement with Dr. Klotzsch. The agreement has been concluded, and now the method is published, that it may be tried and tested as widely as possible by comparative experiments, similar to those made by Dr. Klotzsch himself. The cost of it is stated not to exceed 1*s.* 6*d.* per acre in Germany.

It is very desirable that this method should be tried in the British Islands, and as the season for trying it now approaches, I have here given Dr. Klotzsch's account entire.

(Signed) WILLIAM GREGORY,
Professor of Chemistry at the University of Edinburgh.

It is not needful to offer any apology for the insertion of the above very important communication, which we find in the appendix to a recent work by Baron Liebig on the circulation of the juices, which Dr. Gregory, the editor of that work, introduces with the following observation:—

"After the preceding pages were in print, I received

from Baron Liebig a copy of the Journal of the Agricultural Association of the Grand Duchy of Hesse (Darmstadt), No. 7, dated 15th February, 1848, containing the account of a method proposed by Dr. Klotzsch (Keeper of the Royal Herbarium, Berlin, and a distinguished botanist and vegetable physiologist,) for preventing the ravages of the potato disease: they are such as materially to strengthen the opinions expressed by Baron Liebig on this subject."

TABLE,

Showing the amount of moisture in vegetable substances according to the analysis of Boussingault.

The substances were dried at a temperature considerably above that of boiling water, or 110° Centigrade.

	Water.		Dry matter.
1000 parts of Wheat contained of	145	—	855
— Rye	166	—	834
— Oats	208	—	792
— Wheat Straw	260	—	740
— Rye Straw	187	—	813
— Oat Straw	287	—	713
— Potatoes	759	—	241
— Beet	878	—	122
— Turnips	925	—	075
— Jerusalem Artichoke . . .	792	—	208
— Peas	086	—	914
— Pea Straw	118	—	882
— Clover Stalk	210	—	790
— Stalk of Jerusalem Artichoke	129	—	871

Composition of manure, dried in vacuo at 110° Centigrade.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Salts and Earths.
1	32.4	3.8	25.8	1.7	36.3
2	32.5	4.1	26.0	1.7	35.7
3	38.7	4.5	28.7	1.7	26.4
4	36.4	4.0	19.1	2.4	38.1
5	40.0	4.3	27.6	2.4	25.7
6	35.5	4.3	27.7	2.0	31.5
Mean . .	35.8	4.2	25.8	2.0	32.2

This manure obviously contained a great deal more of salts and earthy matter than belonged to the organic elements which accompany them in these analyses.

Composition of various animal and vegetable substances. 100 parts.

LIGNIN OR WOODY FIBRE.

Carbon	49.80
Oxygen	44.62
Hydrogen	5.58
	100.00 *Prout.*

GUM.

Carbon	42.68
Oxygen	50.95
Hydrogen	6.37
	100.00

Berzelius.

CANE SUGAR.

Carbon	44.99
Oxygen	48.60
Hydrogen	6.41
	100.00

Berzelius.

GRAPE SUGAR.

Carbon	36.71
Oxygen	56.51
Hydrogen	6.78
	100.00

Saussure.

STARCH.

Carbon	44.25
Oxygen	49.08
Hydrogen	6.67
	100.00

Berzelius.

VEGETABLE GLUTEN.

Carbon	55.22
Hydrogen	7.42
Nitrogen	15.98
Oxygen with Phosphorus and Sulphur	21.38
	100.00 *Jones.*

VEGETABLE ALBUMEN.

Carbon	55.01
Hydrogen	7.23
Nitrogen	15.92
Oxygen with Prosphorus and Sulphur	21.84
	100.00 *Jones.*

VEGETABLE CASEINE.

Carbon	54.14
Hydrogen	7.15
Nitrogen	15.67
Oxygen and Sulphur	23.04
	100.00 *Schern.*

ANIMAL ALBUMEN.

Carbon	54.84
Hydrogen	7.09
Nitrogen	15.83
Oxygen with Prosphorus and Sulphur	22.24
	100.00 *Mulder.*

ANIMAL FIBRINE.

Carbon	54.56
Hydrogen	6.90
Nitrogen	15.72
Oxygen with Phosphorus and Sulphur	22.82
	100.00 *Mulder.*

ANIMAL CASEINE FROM MILK.

Carbon	54.825
Hydrogen	7.153
Nitrogen	15.628
Oxygen and Sulphur	22.394
	100.000

ANIMAL GELATINE.

	Isinglass.		Calf's Foot.	
Carbon	50.557	—	50.960	
Hydrogen	6.903	—	7.188	
Nitrogen	18.790	—	18.320	
Oxygen	23.750	—	23.532	
	100.000	—	100.000	*Schern.*

HORNY SUBSTANCES.

HAIR.

Carbon	51.529	
Hydrogen	6.687	
Nitrogen	17.936	
Oxygen and Sulphur	23.848	
	100.00	*Schern.*

BUFFALO HORN.

Carbon	51.990	
Hydrogen	6 717	
Nitrogen	17.284	
Oxygen and Sulphur	24.009	
	100.000	*Schern.*

WOOL.

Carbon	50.653	
Hydrogen	7.029	
Nitrogen	17.710	
Oxygen and Sulphur	24.608	
	100.000	*Schern.*

Feathers are of a similar composition to horn and wool, but contain somewhat more oxygen.

FATS.

	Hog's Lard.		Mutton Fat.
Carbon	79.098	—	78.996
Hydrogen	11.146	—	11.700
Oxygen	9.756	—	9.304
	100.000	—	100.000

Chevreul.

ON THE PRESERVATION OF ANIMAL AND VEGETABLE SUBSTANCES.

For the best methods of effecting the above object we have the high authority of Chaptal, to whom agriculture is indebted for a very valuable work, containing much scientific and practical information upon most branches of rural economy. Though much light has been thrown upon some departments of agricultural chemistry since his work was written (1829), nothing has been discovered to affect the correctness of his views on the above subject; we cannot do better, therefore, than to quote his own words, which the reader will find exceedingly interesting, and of the most practical kind:—

Each product of agriculture has its season; there are few which the earth yields at all times. From this well-known truth there will result two incontestable facts; the first of these is, that in the years of abundance the production is greater than the consumption, and consequently, a part is lost, and the remainder sold at a low price; the second is, that the consumption of the greater part of the articles of agricultural produce takes place within one year, whilst, if the agriculturist had sure means of preserving them, it might be prolonged indefinitely, and thus the sale of them rendered more profitable. The question of the best manner in which the productions of the earth may be preserved, is, then, one of the most important to be solved in rural economy.

Before making known the processes by which, as we have learned from experience, agricultural products may be preserved free from change, it is necessary to cast a glance upon the causes by which that change is produced.

The natures of all bodies which have ceased to live are changed as soon as the physical or chemical laws by which they were governed cease to act; the elements of which they were composed then form new combinations, and consequently new substances. Whilst an animal lives, or a plant vegetates, the laws of chemical affinity are continually modified in its organs by the laws of vitality; but when the animal or plant ceases to live, it becomes entirely subject to the laws of chemical affinity, by which alone its decomposition is effected.

The principles of the atmospheric air, which is imbibed by the organs of *living* bodies, whether animal or vegetable, are decomposed and assimilated by them, whilst *dead* bodies are decomposed by its action. Heat is the most powerful stimulant of the vital functions, yet it becomes after death one of the most active agents in the work of destruction. Our efforts, then, for the preservation of bodies ought to be directed to counteracting or governing those chemical agents, from the action of which they suffer, and we shall see that all the methods which have been successful are those which have been formed upon this principle.

The chemical agents which exert the most powerful influence over the products of the earth are air, water, and heat: the action of these, however, is not equally powerful over all classes of plants; the soft and watery, and those which approach the nearest to animal matter, decompose most rapidly; the principles of such are less coherent, less strongly united, than of others, so that the action of disorganizing agents upon them is prompt and effectual.

All the methods now employed for the preservation of bodies consist in so far changing their nature as to deprive them of the elements of destruction contained within their own organs, or in secluding the substances to be preserved from contact with the destructive agents mentioned in the preceding paragraph, or in causing them to imbibe some other substances, the anti-putrescent qualities of which counteract all action, whether of internal or external agents.

On the Preservation of the Fruits of the Earth by Drying.

In all vegetable products, water exists in two different states, one part of it being found free, and the other in a state of true combination: the first portion not being confined, except by the covering of the vegetable, evaporates at the temperature of the atmosphere; the second is set free only at a temperature sufficiently high to decompose the substances containing it. The first, though foreign to the composition of the vegetable, enters into every part of it, dissolves some of its principals, serving as a vehicle for air and heat, and being converted by cold into ice. By these several properties it greatly facilitates decomposition.

The second portion, from which no evil of the kind arises, is found combined and solidified in the plants, and its action is thus neutralized. Drying, then, consists in depriving the product to be preserved of the water contained in it in a free state, by heat; and from what has been observed above, it follows, that too great a degree of heat must not be applied, as, in consequence, the state and organization of the substance would be changed by a commencement of the decomposition of its constituent principles: the temperature should never be higher than from 95° to 113° Fahrenheit.

Drying can be performed either by the heat of the sun, or in stove-rooms. In the southern climates the heat of the sun is sufficiently powerful to dry the greater part of the fruits, and thus to preserve them unaltered. The drying is effected by exposing them to the rays of the sun upon hurdles, or slates, where they will be protected from rain, dust, and injury from animals. Practice alone is sufficient to enable one to judge of the degree to which each kind of fruit must be dried in order to its preservation.

When the outer skin or rind of a fruit is of a kind to prevent the water from passing off freely, incisions are made in the rind to facilitate its evaporation. In this manner are prepared most of the dried fruits, which form so considerable an article of commerce between the south and north.

Those fruits which contain much sugar, as plums, figs, musk grapes, &c., may be prepared in the above manner, and preserve nearly all their qualities: but the acid fruits acquire a disagreeable sharp taste by the concentration of the juices; some of them, however, may be kept advantageously in this way.

In the hottest countries the process of drying is often commenced by subjecting the fruits to the heat of an oven, after which they are exposed to the heat of the sun. Some kinds of fruits are thrown into a weak ley, till their surface becomes wrinkled, when they are taken out, carefully washed in cold water, and afterwards dried in the sun. Cherries, particularly, are treated in this manner. When the heat of the sun is not sufficiently great to evaporate all the water contained in the pulp of large fleshy fruit, they may be cut in pieces and then dried; in this manner apples and pears are prepared for keeping.

But this method is neither speedy nor economical enough for such preparations as have but little value in commerce, and which can never supply for domestic purposes those whole fruits which can easily be preserved from one season to another; it is therefore customary to perform the drying either in stove rooms or ovens. In the first case the fruits, after being cut, are placed upon hurdles arranged in rows in a chamber heated to 112°; in the second, the fruits are put into an oven from which bread has been just drawn; this is repeated if the fruits be not sufficiently dried the first time.

Some of the fruits above referred to may be dried without being cut: of this kind are the tender pears, which cannot be preserved fresh through the winter. These are first peeled, and then thrown into boiling water, after which they are put upon hurdles in an oven heated less than is required for bread. After an interval of three or four days, the pears are again exposed to the same degree of heat, having been, however, first flattened between the palms of the hands, whence they have acquired the name of *pressed pears*.

Fruits prepared in either of the above ways are susceptible of fermentation upon being soaked in water, and they must serve to make a cheap and useful drink.

In those countries where these fruits abound, the drying of them is commenced about the 1st of August, and those are made use of which then fall from the trees. In autumn, when the harvest is gathered in, the soundest and finest fruits are carefully selected to be used fresh, whilst the rest are dried and preserved in a place free from moisture, to be employed in making drinks.

The herbage which serves as food for domestic animals can be preserved only by drying, and this, in all countries, is practised at the time of cutting. Fodder which is imprudently stacked up whilst still damp, ferments, and the heat thus produced is sufficient to change the quality, produce mouldering, and is sometimes even great enough to set the whole on fire.

There are some fruits which may, by a few slight precautions, be preserved throughout the year. The first of these precautions is, that of depriving their surface of all moisture before putting them up; and the second consists in keeping them in dry places, where the temperature will

constantly be between 50° and 40° Fahrenheit; the third, in separating the fruit, so that they shall not come in contact. I have seen apples preserved in this manner eighteen months. It is necessary to be particular in selecting fruit for preservation; that only should be taken which is perfectly sound.

Wood and other portions of vegetables, and various animal substances, are likewise preserved by drying; this process increases their hardness, and renders them less accessible to the action of air, insects, and other destructive agents.

The process of drying is not confined to preserving fruits from decomposition: it furnishes the means of securing their juices unaltered for the formation of extracts of them.

The Preservation of the Fruits of the Earth by secluding them from the action of the air, water, and heat.

The atmospheric air coming in contact with fruits, deprives them of carbon, and forms carbonic acid.

Fruits exposed to the solvent action of water, suffer decomposition by having the affinity existing between their constituent principles weakened, and at length destroyed. Heat dilates the particles of bodies, and thus diminishes the forces of cohesion and attraction, and favours the admission of air and water.

The combined action of these three agents produces very speedy decomposition; the effect produced by any one of them is slower, and the results different. So that in order to preserve fruits from decomposition, it is necessary to guard them from the power of these three destroyers.

In several European countries, particularly in the North, roots of all kinds are preserved merely by secluding them entirely from the air, heat, and water. This is done by digging deep ditches in a dry soil, upon a spot a little elevated, and depositing in them the roots, which are afterwards covered over with a layer of earth, of sufficient thickness to prevent them from suffering from the frost; over the the whole is then laid a bed of straw, broom, or fern, in order to protect them from rain, and from the water of melting snows which might filtrate through into the pit.

Roots, to be kept well, must have their surfaces entirely free from moisture before being thus buried.

The roots have in themselves a preserving principle which does not exist in a dead plant, or one that has terminated its period of vegetation: they have as yet lived but a portion of their vegetable life; they have not formed the seeds, which secure the continuance of their species; and to fulfil this great design of nature, they profit by every circumstance which can favour and confirm their vegetation; but when placed for a time beyond the action of air, water, and heat, their organs remain at rest till again excited by the presence of these powerful agents. As dead bodies do not retain their animating principle, the energies of which are only suspended in roots, grains, &c. during the winter, so they suffer decomposition, though less rapidly, from the contact of air, heat and moisture.

In the way of which I have just spoken, beets, carrots, potatoes, and many other vegetables, may be preserved uninjured, till summer. Vegetables may likewise be preserved by heaping them up in barns to the height of five or six feet, care being taken to cover them well with straw or hay at the commencement of the severe cold weather. Should the roots in these heaps begin to vegetate, they must be removed, and thus their further development checked.

Thomas Dallas has published some very important observations upon the modes of treating potatoes which have been affected by the frost. With us such potatoes are rejected, as being unfit either for food or for furnishing fecula. The able agriculturist considers them in three different states. 1. When they are slightly touched by the frost; 2. when the outer portion of their substance is frozen; and 3. when they are frozen throughout.

In the first case, he finds that nothing more is necessary than to sprinkle the roots with lime to absorb the water from under the skin, which would speedily occasion their complete decomposition. In the second instance, he causes the potatoes to be pared, and thrown for some hours into water, slightly salted. When the potatoes are completely frozen, he finds them yield, upon distillation, a spirituous liquor, resembling the best rum, and affording much more alcohol, and that of a better quality, than can be procured from the roots before freezing.

The preservation of grains has always been an object both with governments and agriculturists, and it is a

peculiarly interesting one, because bread forms so large a portion of the nourishment of Europeans, and because the scarcity and high price of it has been the cause, or the pretext, for popular discontent and insurrections.

The art of preserving grains unchanged, besides obviating this evil, presents the additional advantage to the agriculturist of enabling him to make a good harvest compensate for a bad one, by maintaining the price of bread stuff at a rate suitable alike for the consumer and the producer; and thus avoiding those periodical successions of high and low prices, of abundance and scarcity, which disturb social order, and give rise to excesses prejudicial to all.

It appears that the people of the most ancient times preserved their grains uninjured through several years, merely by secluding them entirely from the action of air and moisture. The Chinese have from time immemorial preserved their grains in pits, which they call "teon." These pits are either hewn out in rocks free from chinks and humidity; or, what is still better, they are dug in a firm dry soil. If there be any danger of humidity about the pits, they are lined with straw, or wood is burned in them, to harden and dry the earth. The grain is not put into the pits till some months after the harvest, nor till it has been well dried in the sun; it is then covered over with mats made of straw, and these again by a bed of earth, well beaten down, that it may not be penetrated by water.

Varro, Columella, and Pliny, inform us that the ancients preserved their grain in ditches hollowed out of rocks or dug in the earth, the sides of them being lined with straw. Quintus Curtius relates that the army of Alexander experienced great privation upon the banks of the Oxus, because the inhabitants of the country preserved their corn in subterranean pits, the situation of which was known only to those who dug them.

The grains which are consumed in Algiers and Tunis, or which are exported thence, are, after having been well dried in the sun, deposited in trenches cut in the rocks, and having their sides lined with straw. The same mode is followed in Malta, Sicily, Spain, and Italy.

In order to secure a perfect preservation of grain in trenches, it is necessary to make use of certain precautions, without which the entire loss of it must be hazarded; the means of security are as follows:—

First, the grain should never be put in trenches till it is perfectly dry; it must therefore be first exposed to the sun for several days, or dried upon a kiln, and frequently turned, that every part may be equally dry.

Second, in constructing the trenches, choice must be made of a dry soil, or a rock free from chinks, that there may be no danger either from dampness or the infiltration of water. The walls of the trenches may be made with such cement as the Romans used in the construction of their aqueducts; this is composed merely of lime and pebbles; the walls of these aqueducts were raised in frames, and the surface of them carefully polished. I have visited the remains of some of them in various parts of France, and have found them everywhere present the same appearance. I am convinced that this cement is impenetrable by water, and of a solidity more than sufficient for constructing the sides of trenches.

Third. The third precaution consists in excluding the air completely. If this fluid should gain admittance, it must necessarily convey in at the same time moisture and oxygen, the two principles of germination. The presence of air will likewise favour the existence and multiplication of insects; whilst, if the trench be full of grain, and well closed, all the air which it contains will be changed into carbonic acid, and the insects will remain torpid. This last assertion is, as we shall shortly see, supported by the results of the experiments which have been made by the Board of Provisions of War, for the purpose of ascertaining the best modes of preserving grain.

The Board of Provisions of War, under the direction of the Count Déjean, has performed a series of well-directed experiments, from which excellent results have been obtained. The apparatus used in them consisted of lead receivers, hermetically sealed, and having all their joinings soldered. Meal and grain full of weevils were inclosed in these receivers: when these were opened, at the end of a year, it was found that no injury had been done by the weevils; they were all either dead or in a state of torpor. In one of the receivers there was found a collection of grains adhering to each other in a mass about as large as a middle-sized apple. This arose from the entrance of air and moisture through a hole the size of a pin, accidentally left unsoldered in one of the joints.

The elder Ternaux caused trenches to be formed and filled with corn in the beautiful field of Saint Arven. In order to be sure of the preservation of the grain, he caused the trenches to be opened from year to year, and the results were always satisfactory.

Instead of constructing trenches of stone without the farm buildings, there might be built within them bins of stone, of a size proportioned to the size of the farm, and with the openings covered in such a manner as to exclude the air. The same purpose may be answered by chests and tubs of wood, having their outsides covered with a thick coat of paint. The great earthern jars in which oil is kept in the South, are likewise very good for keeping grain in.

Either of these methods is preferable to that of storing grain in such granaries as are commonly used, since the utmost care will not entirely protect it from moisture, insects, mice, &c.; nor will it often remain in them unchanged for any considerable time.

Corn which is housed without being thoroughly dried, or which is stored in a damp place, acquires a musty smell and taste, which render it unfit for the customary uses; but as this alteration affects only the outer covering, and not the substance of the kernel, it may be easily removed by throwing upon the grain double its weight of boiling water, carefully stirring the mass till the water becomes cold. The spoiled kernels which swim upon the top must then be removed, the water poured off, and the grain spread to dry.

Meats and the most delicate vegetables may be preserved for any length of time by a process of a simple and very practicable kind, discovered by M. Appert. It consists in putting the meat or vegetable to be preserved in strong bottles, as closely packed in them as can conveniently be done to within three inches of the top, and closing the bottles with very good and perfect corks, well forced in with a mallet. The bottles are then placed in a boiler of cold water up to the neck, and the temperature raised to the boiling heat, at which it must be kept for a sufficient time for ordinary cooking. The fire must then be removed, or the water drawn off by a syphon, and when the bottles are cool, their mouths should be further secured by covering them well with melted resin. All the oxygen of the

air contained in the interstices of the meat or vegetables being by this process converted into carbonic acid by union with some of the carbon of the substance, no further chemical change can take place; in other words, both decay and putrefaction are effectually prevented by the absence of free oxygen in the bottle, and its perfect exclusion. Wide-mouthed bottles or jars may be used for this purpose, provided they be perfectly closed. But a still better method of effecting this object has been recently adopted, which consists in putting the meat or vegetables in cylindrical tins; a top with a pin hole is then soldered on: the vessels are then placed in a boiler, with the water reaching to about three-fourths of their height, and after being boiled a sufficient time, the pin holes at the tops are closed with solder. Meat and vegetables thus preserved will keep any number of years without undergoing any perceptible change, and therefore the process is well adapted for the preservation of fresh food for long voyages, and as an article of commerce in distant colonies, where meat is exceedingly cheap, particularly in Australia, where vast quantities of fine meat is boiled down merely for the fat.

A Table of the British Strata,

ARRANGED IN THE ORDER IN WHICH THEY OCCUR,

COMMENCING WITH THE UPPERMOST OR MORE RECENT.

ALLUVIUM, OR ALLUVIAL BEDS.

	Character.	*Localities.*
Deposits of Rivers .	Sand, mud, or silt.	Banks and bottoms of rivers, deltas at the mouths of rivers, bottoms of lakes.

DILUVIUM, OR DILUVIAL DRIFT.

Ancient Superficial Deposits	Sand, clay, and gravel, composed of drifted fragments of strata, both near and distant, containing the bones of elephants and other large animals.	Everywhere in valleys and the plains beyond. Often on the sides and summits of hills and high inland levels. London, Oxford, Gloucester, Harwich, Valley of Bath, &c.

TERTIARY STRATA ABOVE THE CHALK.

Crag	Sands, clays, and marls, with imbedded shells and the remains of land animals.	Coasts of Norfolk, Suffolk, and Essex, resting upon the London Clay, and in some places upon the Chalk.
Freshwater and Marine Beds of the Isle of Wight	Limestone, with clay and sand; sandy and clayey limestones; freshwater and marine shells.	Headon Hill, Isle of Wight.
Bagshot Sand	Sands, sandstones, and flint pebbles.	Bagshot Heath, Hampstead and Highgate Hills.
London Clay.........	Lead-colour or blue clay, containing nodules of cement-stone, with fossil shells and seeds.	London, Isle of Sheppy, Highgate Hill, Richmond, Coast of Hampshire.
Plastic Clay	Blue, yellow, and white clay; sands; and flint pebbles, much water-worn and rounded.	Blackheath, Reading, Poole, Alum Bay, Isle of Wight.

NEWER SECONDARY STRATA.

		Character.	Localities.
CRETACEOUS SYSTEM.	*Upper Chalk*	Soft marking chalk, with beds and nodules of flint.	Marlborough Downs, Salisbury Plain, South Downs, Dover Cliffs, &c. &c.
	Lower Chalk	Harder than the above, with but few flints.	Flamborough Head, Warminster, Shakspear's Cliff.
	Chalk Marl or Malm	Clayey grey chalk, without flints, passing into grey sand and marl. Firestone.	Benson, Oxfordshire; Vale of Pewsey, Wilts; Guildford, &c.; Folkstone.
	Upper Green Sand	Sand and sandstone, with particles of silicate of iron.	Devizes, Warminster, Wantage, Vale of Pewsey, Shaftsbury.
	Lower Green Sand.	Sands and sandstone, with beds of chert and limestone (Kentish Rag.) Building sandstone and whetstone of Devon.	Black Down, Somerset, and Devon; Maidstone, Kent.

MIDDLE SECONDARY.

		Character.	Localities.
WEALDEN SYSTEM.	*Wealden Clay and Iron, or Hastings Sand*	Weald clays, with Petworth marble, Purbeck beds of limestone; Tilgate grit, or Hastings sands.	Wealds of Kent and Sussex; Isle of Purbeck; Lulworth; Wooburn, Bedfordshire.
OOLITE SYSTEM.	*Portland Stone*	Imperfect gritty limestone, containing beds and nodules of chert. Building-stone of London.	Isle of Portland; Swindon; Aylesbury; Tisbury, Wilts.
	Kimmeridge Clay	Blue shaly clay.	Shotover Hill, Oxford; Isles of Purbeck and Portland.
	Coral Rag	Imperfect limestone, with shells and coralline fossils.	Calne, Wilts; and Kirby Moor, Yorkshire.
	Calcareous Grit	Siliceous and shelly sandstone.	Abingdon; Weymouth; Filey, near Scarboro'.
	Oxford Clay	Blue and yellow clay, with melbury marble turtle stone.	Oxford; Valley of the Thames; Bedford; Vale of Blackmoor, Dorset.
	Kelloway Rock	Coarse sandy limestone, with ammonites and other shells.	Kelloway Bridge, near Calne, Wilts.

MIDDLE SECONDARY—*continued*.

		Character.	*Localities.*
OOLITE SYSTEM—*continued*.	*Corn Brash*	Imperfect limestone, often blue and sandy.	Malmsbury and Trowbridge, Wilts; Atford, Wroxhall, Chippenham, Wilts.
	Forest Marble	Coarse slaty limestone, abounding in shells.	Hinton, nr. Bath; Melbury, Dorset; Frome.
	Stonesfield Slate ...	Calcareo-siliceous slate, sometimes passing into sand with shale.	Stamford; Stonesfield, Oxon; Hinton, near Bath; Cleaveland Hills, Yorkshire.
	Great Oolite	Yellow freestone, with fragments of shells (Bath stone).	Farley and Coomb Downs; and Bathford Hill, near Bath.
	Fullers' Earth.......	A brown clay, containing fullers earth.	Sides of the hills round Bath; Olddown and Fortnight, near Bath.
	Inferior Oolite	Coarse freestone, abounding in shells, reposing upon deep beds of calcareous sand, with masses of marl.	Bath, Doulting, Mendip Hills, and Ham Hill, Somerset; Dundry Hill; Cotswold Hills, Gloucestershire; Beechen Cliff, and Beacon Hill, Bath; Yeovil and Ilminster, Somerset.
	Lias	Blue slaty marl or clay, with beds of blue and white Lias limestone, containing large ammonites and fossil bones of reptiles.	Whitby, Yorkshire; Vale of Bath; Lyme Regis, Dorset; Churton and Street, Somerset, &c. &c.

OLDER SECONDARY STRATA.

RED SANDSTONE SYSTEM.	*New Red Sandstone, or Red Marl*	Red clay or marl. Sands and sandstones, with interspersed and accumulated beds of pebbles of older rocks. Gypsum, rock-salt, and brine springs.	Cliffs at Sidmouth; Plains of Worcester and Cheshire; Worcestershire; Warwickshire; Nottinghamshire, &c. Dawlish; Exeter; Western Valleys of Somerset; Shropshire, and many Midland Counties; Namptwich; Droitwich.
	Magnesian Limestone	Yellowish sub-crystalline limestone. Building stone of York Minster and the Houses of Parliament.	Nottingham, Mansfield, Notts; Knaresborough, Yorkshire; Sunderland; Wookey Hole, Somerset; Exeter.

OLDER SECONDARY STRATA—*continued.*

		Character.	*Localities.*
CARBONIFEROUS SYSTEM.	*Coal Measures*	Beds of coal and culm, alternating with layers of shale, sand, and hard gritstone, and sometimes limestone.	Northumberland, Scotland, Derbyshire, Lancashire, Shropshire, Staffordshire, North and South Wales, Gloucestershire, Somerset.
	Millstone Grit	Coarse siliceous sandstone, containing mica and pebbles. Flagstones of London, and grindstone beds.	Accompanying the coal measures from Derbyshire to Northumberland.
	Mountain or Carboniferous Limestone	Blue or reddish compact limestone; secondary marble of Derbyshire, abounding in caverns and deep fissures, and containing ores of lead and calamine. Sometimes alternating with beds of shale, chert, and gritstone, and penetrated with trap-rocks; often full of shells and corals.	Mendip, Somerset; Hot Wells, Bristol; South Wales. Banks of the Wye, Monmouthshire; Matlock, &c. Derbyshire, Lancashire, Westmoreland, Cumberland, and Northumberland. Derbyshire.
DEVONIAN, OR OLD RED SANDSTONE SYSTEM.	*Old Red Sandstone.*	Sandstones and conglomerates of pebbles; limestones called cornstones, and marls alternating with slaty beds of sandstone.	Cumberland; Hereford; Shropshire; Monmouth; Brecon. Mitchel Dean, Gloucestershire, and Portishead Point, near Bristol. Several parts of Scotland.
	Devonian Rocks	The so-called Greywacke rocks and slates of Somerset, North and South Devon, and Cornwall, with slaty limestones and secondary marbles.	Quantock, Somerset; Exmoor; Ilfracombe, Coomb-Martin, and Kingsbridge, Devon; St. Colomb, Portreath, and Truro, Cornwall; Plymouth and Babbicomb, Devon.
SILURIAN SYSTEM.	*Upper Silurian*	Blue and grey clayey limestones; dark shales and flagstones, containing marine shells and fishes.	Ludlow Castle, Shropshire; Aynestry and Woolthorpe, Herefordshire.
		Crystalline blue and grey limestones, with various fossils.	Dudley Castle, Worcestershire; Wenlock Edge, Iron Bridge, Shropshire.
		Dark grey shale, with nodules of sandstone.	Wenlock, Shropshire.

OLDER SECONDARY STRATA—*continued.*

		Character.	Localities.
SILURIAN SYSTEM—*continued.*	*Lower Silurian*	Caradoc shelly limestone, and greenish sandstones, with corals and shells.	North and South Wales; Horderly, Shropshire; May Hill, Gloucestershire.
		Llandeilo flags and limestone; freestone grits and limestone; dark-coloured flags; beds of schist, with shells and trilobites (a fossil crustaceous fish).	Llandridod, nr. Builth; Radnorshire.
CAMBRIAN SYSTEM.	*Plynlimmon Rocks*	Slates with beds of conglomerate.	Plynlimmon, Cardigan.
	Bala Limestone	Dark limestone, with slates; a few fossils.	Bala, Merionethshire.
	Snowdon Rocks	Fine-grained blue roofing slates, with few fossils.	Snowdon, Caernarvonshire.
	Cambrian and Cumbrian Slates	....	Longmind Hills, Shropshire; Barmouth; Cardiganshire; Keswick and Grassmere, Westmoreland; Mull of Galloway; and Lammermuir Hills, Scotland.

PRIMARY STRATIFIED CRYSTALLINE ROCKS.

Chlorite Schist	Composed of quartz and chlorite, laminated.	Ben Lawers, Ben Lomond, Loch Awe, Mull of Cantyre, Scotland.
Mica Schist	Laminated and granular, and composed principally of quartz and mica.	
Gneiss.................	Laminated and granular, and composed of quartz, felspar, and mica. The strata of this and the above rocks are very much contorted or twisted, and they are sometimes more or less associated with crystallized limestone, or marble, hornblende slate, granular and compact quartz rock, &c.	Grampian Hills, Benmore Hills, Loch Rannoch, Loch Gil, Isles of Tiree and Col, and Western Isles, Scotland.

UNSTRATIFIED ROCKS.

	Character.	*Localities.*
Granite	Grey, red, and white, and composed of crystalline grains of quartz, felspar, and either mica or hornblende.	Aberdeen, Peterhead, Cairn Gorm, Scotland; Mount Sorrel, Leicestershire; Malvern Hills, Worcestershire; Dartmoor, Devon; Banks of the Tamar, and Lands End, Cornwall.

TRAP ROCKS.

Porphiry *Green Stone* *Basalt* *Toadstone* *Compact Felspar* *Syenite* *Serpentine*	These are unstratified and crystalline rocks, which, in a molten state, have penetrated, fractured, and upraised many of the stratified rocks, and produced dikes and faults.	Mines and mining districts of Cornwall; Salisbury Craigs; Edinburgh; Isle of Staffa; Clee Hills, Shropshire. Mountain limestone, Derbyshire; Wrekin Hill, Shropshire; Malvern Hills, Worcestershire; Lizard, Cornwall.

GLOSSARY OF TERMS

WHICH MAY NOT BE FAMILIAR TO THE READER.

Acetification.—That change by which acidity is produced, when wine or beer is converted into vinegar by exposure to the air at a moderate temperature.

Acids.—Substances the common character of which is sourness. But sourness is not in all cases a quality of those substances which, in chemical language, are called acids. The chemical explanation of an acid is, that it is a substance which has the property of uniting with another substance, called a base, either an alkali or an earth, and forming with it a salt. The salt thus formed derives its name from the particular acid and base from which it is produced; thus acetic acid (the acid of vinegar) united with the alkali potash, forms a salt called *acetate of potash*. Sulphuric acid forms with the same base sulphate of potash, and with lime, sulphate of lime. The acids derived from vegetable and animal substances are called *organic* acids, and those derived from mineral substances are denominated *mineral* acids.

Acid, Citric.—The acid of lemons. It is found in some of our native fruits.

—— *Carbonic.*—So called from being the result of the union of carbon with oxygen; united with a base it forms a salt called a carbonate. With lime, for instance, it forms carbonate of lime (limestone); with potash, carbonate of potash, &c. It is driven off from limestone by burning. It is produced from its elements by combustion of coals, wood, oil, &c., and by fermentation of beer and of vegetable and animal substances.

—— *Fluoric.*—A mineral acid of exceedingly corrosive character; united with bases it forms the salts called *fluates*. With lime, for instance, it forms fluate of lime (Derbyshire spar).

—— *Formic.*—The acid of ants. The salts produced by its union with bases are called *formates*.

Acid, Gallic.—The acid of gall nuts, which by its union with oxide of iron forms ink. Its salts are called *gallates.*

—— *Hydrochloric.*—See Muriatic Acid.

—— *Lactic.*—The acid of sour milk. Its production and effect on milk are described under the head of milk in this work. The salts it forms with bases are called *lactates.*

—— *Malic.*—The acid of apples, gooseberries, currants, and the service tree. Its salts are called *malates.*

—— *Muriatic.*— The acid of sea salt. Its salts are called *muriates.*

—— *Nitric.*—The acid of nitre, which is a *nitrate* of potash.

—— *Oxalic.*—The acid of sorrel. Its salts are called *oxalates.*

—— *Phosphoric.*—The acid of bone earth, which is called a *phosphate* of lime and magnesia. Its other salts are called *phosphates.*

—— *Sulphuric.*—The acid of sulphate of lime and other salts called *sulphates.*

—— *Tartaric.*—The acid produced from the tartar of wines, which is a *tartrate* of potash. Its other salts are called *tartrates.*

—— *Uric.*—An acid produced by the putrefaction of urine, and formed from a substance in that fluid called *urea.*

Acidity.—That property of chemical substances which affects the palate with the sensation of sourness.

Affinity, Chemical.—The peculiar attraction of one atom for another.

Albumen.—A compound substance found both in animals and vegetables, of which the white of egg is almost a pure specimen.

Alcohol.—The pure spirit of wine, from which the water has been removed by repeated distillations.

Alkalies.—Substances which serve as bases to form salts with acids. Soda and potash are called fixed mineral alkalies, and ammonia is called a volatile alkali. Besides these, there are several vegetable alkalies of very compound and generally poisonous nature.

Alkaline Earths.—Lime and magnesia are the principal earths called by this name.

Alluvium.—Gravel, sand, and earth, sometimes called drift, from its being produced by the violent action and transporting power of streams and torrents. Recent deposits of water.

Alumina.—The plastic and adhesive substance in clays.

Ammonia.—A volatile and pungent alkali, produced abundantly by the putrefaction of animal substances. It always exists in the atmosphere, and is the source of the nitrogen of plants. Its elements consist of 1 atom of nitrogen and 3 atoms of hydrogen.

Ammonites.—Large fossil shells found abundantly in many of the secondary strata, with spiral folds, somewhat resembling a ram's horn.

Amorphous.—A term applied to rocks and minerals, signifying shapeless.

Analysis.—The chemical operation by which a compound substance is separated or divided into more simple principles, or into their ultimate elements.

Anthracite.—A mineral coal containing no bitumen, and burning without flame, commonly called culm.

Antiseptics.—Substances which prevent the decay and putrefaction of animal and vegetable matters. Spirits of wine, creosote, common salt, sugar, corrosive sublimate, and some salts of metals, are such substances.

Arenaceous.– Sandy; from *arena*, sand.

Argillaceous.—Clayey; from *argilla*, clay.

Augite.—A mineral of nearly a black colour, one of the products of volcanoes, and a constituent of some trap rocks.

Azote.—The diluting or indifferent gas which forms the greater part of the atmosphere, of which oxygen forms the other part. It is called *indifferent*, because, unlike oxygen, it has little or no affinity for other substances.

Basalt.—A very common trap rock. A dark compact rock of great hardness, often forming pillars, as at the Giants' Causeway, and the Cave of Fingal, in the Isle of Staffa. It is chiefly composed of two minerals, felspar and augite, and contains much iron.

Basin is the term used to express the hollow in which strata are deposited. Thus we have the Basin of Paris and the Basin of London, which are depressions in the chalk which contain the tertiary strata of those places.

Bitumen.—Mineral pitch, or asphaltum.

Bituminous Shale.—Shale, or clayey layers, containing bitumen.

Boulders.—Water-worn and rounded blocks of stone.

Calcareous.—Consisting of carbonate of lime, or chalk.

Calcareous Rock.—Limestone: *calx*, lime.

Calcareous Spar.—Crystallized carbonate of lime.

Calcedony.—A siliceous mineral, resembling common flint.

Calcination.—Burning of earthy substances, as burnt lime is calcined limestone.

Carbon.—The solid, inflammable substance of coal and wood.

Carbonates.—Salts formed by the union of carbonic acid with bases, as carbonate of lime, carbonate of soda, &c.

Carbonate of Lime.—See Carbonates.

Carboniferous.—A term usually given to strata in which coal is found: *carbo*, coal, and *fero*, to bear.

Caseine.—The curd of milk, originally produced by vegetation in the organs of plants.

Chalk.—A white and soft limestone, the uppermost of the secondary series of strata.

Chert.—A siliceous or flinty mineral, found in the green-sand and other strata.

Chlorides.—Compounds formed by the union of chlorine with metals and other elements. Common salt is, in fact, a chloride of the metal sodium, though it is commonly called a muriate of soda. It is only a muriate of soda when dissolved in water, by which the elements of water, oxygen and hydrogen, are added to those of the chloride, or dry salt.

Chlorine.—A suffocating gas, and one of the elements of muriatic acid, of which hydrogen is the other.

Combustion.—That violent chemical action called burning, by which the *elements* of the burning body are not destroyed, but enter into new arrangements.

Conglomerate, or Pudding Stone.—Pebbles, or rounded fragments of rock, cemented together by stony matter.

Cornbrash.—A provincial term for a rubbly limestone soil of considerable fertility. It is a member of the Oolite system.

Cornstone.—A red limestone of the old red sandstone, or Devonian series of rocks.

Crag.—The uppermost of the English tertiary strata of Norfolk and Suffolk, provincially so called.

Cretaceous.—Chalky : *creta,* chalk.

Crop out.—The rising to the surface of one stratum from beneath another.

Crystalline.—Formed of crystals, as marble, and loaf-sugar.

Crystallization.—The formation of salts into those regular forms called crystals, each salt assuming a form peculiar to itself.

Decomposition.—The separation of the elements of a body.

Delta.—The silty and sandy deposits at the mouths of great rivers, such as those of the Nile and Ganges.

Diastase.—A substance produced in the very early stage of the germination of seeds, by which their starch, or farina, is converted into sugar.

Dikes.—Veins or masses of trap rock, which have penetrated the softer strata, and sometimes rise above them like a wall. A provincial term for a wall.

Diluvium.—Beds of gravels, sands, or earths, the deposits of ancient floods, which often extensively cover the regular strata.

Dolomite.—A limestone containing magnesia.

Elements.—Those substances are so called which the chemist has not succeeded in decomposing, and are therefore presumed to be simple, or undecomposable substances.

Essential Oils.—Those volatile and aromatic oils obtained by distillation from many vegetable substances. The aroma of

flowers, plants, and fruits, is owing to the essential oil peculiar to each.

Farina.—The floury matter of seeds and roots, and of which the principal part of bread-corn, rice, and potatos consists.

Fault.—A term used by miners for those dislocations of the strata by which their continuity is broken, and by which the strata on one side the fracture are depressed, or raised above those of the other. These faults, as they are called, often cause great embarrassment to miners.

Felspar.—A mineral crystallized substance, the chief ingredient of granite, sometimes exhibiting large angular crystals, as in the granite of Dartmoor, and seen in the pavement of the London bridges.

Fermentation.—That spontaneous chemical action which takes place in dead vegetable substances under the influence of atmospheric air, moisture, and a certain temperature, by which new combinations are formed from their elements, as in the familiar instance of the fermentation of wine and beer. This term is loosely applied to all spontaneous change, both of vegetable and animal matter, though in the latter case, it is more generally called putrefaction; indeed they differ only in their results.

Ferruginous.—Containing iron: *ferrum*, iron.

Fibrine, or Animal Gluten.—The substance of which the muscles of animals and the clot in blood are chiefly composed. It is the same substance as vegetable gluten, or that which is extracted from wheat flour. In addition to the elements of starch, sugar, and woody fibre, it contains nitrogen, phosphorus, and sulphur, and various saline substances.

Fixed Oils.—The oils and fats, whether animal or vegetable, which do not rise by distillation.

Fluates.—Salts formed by fluoric acid with bases (see Fluoric Acid).

Fluor Spar.—Fluate of lime (Derbyshire spar).

Formation.—A group or series of rocks having some common character.

Fossils.—The remains of plants or animals found buried and petrified in the earth.

Fusion.—The melting of mineral substances by heat.

Galena.—The common ore of lead, a sulphuret of lead.

Gas.—Any permanently elastic fluid.

Gault.—A term for those beds of clay which separate the upper and lower green-sand strata.

Gelatine.—Animal jelly. The skins and tendons of animals consist almost entirely of gelatine, the animal basis of leather.

Glaciers.—Those masses of ice and snow found in the elevated bosoms of lofty mountains, such as the Alps, Andes, and Himalaya.

Gluten, animal.—The same substance as Fibrine, which see.

Gluten, vegetable.—This substance is the origin of animal gluten, with which it is identical in all its properties.

Gneiss.—A primary stratified and crystalline rock of similar mineral composition to granite. A German term.

Granite.—An unstratified crystalline rock of igneous origin. It is associated with the oldest or primary stratified rocks, but underlies them all, and also rises above them, forming the sharp or pointed summits of the loftiest ranges of mountains. It is composed of various sized grains of quartz, felspar, and mica. The bridges and paving stones of the streets of London afford specimens of almost every variety of this rock.

Gravity, Specific.—The weights of solids, fluids, and gases, as compared with some standard. 1000 parts by measure of water at 60° Fht. is the standard for fluids and solids: and 1000 parts of atmospheric air at the same temperature is the standard of gases and vapours.

Graywacke, or Grauwacke.—A German term, given to the series of the slaty rocks, the lowest of the secondary strata, corresponding to our Cambrian system. This name has been applied to those slaty rocks of Somerset, Devon, and Cornwall which are now called Devonian.

Green Sand.—The underlying rock of the Cretaceous or Chalk system, deriving its name from the green particles of silicate of iron it contains.

Green Stone.—A trap rock composed of felspar and hornblende.

Grit.—A sandstone composed of coarse-grained sand, such as our grind-stones exhibit.

Hornblende.—A mineral of very dark green or black colour, and an ingredient of many of the trap rocks.

Humus.—The dark, vegetable, decaying matter of mould, and the soil of rich pasture land. The decaying matter of peat bogs.

Hydrates.—Minerals chemically united with water. Slaked lime is a hydrate of lime, and is composed of 1 equivalent of lime and 1 equivalent of water, or, in other words, 28 pounds of lime unites with 9 pounds of water. Many minerals contain water in a dry and solid state.

Hydrogen.—The lightest of all the gases, and one of the elements of water.

Hydrous Salts.—Those salts the crystals of which contain water in a solid form, which is called their water of crystallization. Alum and crystallized carbonate of soda are familiar specimens.

Inorganic.—All mineral elements are called inorganic, to distinguish them from those of which the organs of plants and

animals are composed. The carbon, oxygen, hydrogen and nitrogen of vegetables are called organic, but the ashes which are left when the vegetable is burnt, are called inorganic, or mineral substances.

Kimmeridge Clay.—A stratum of clay belonging to the upper oolite, and underlying the Portland stone, so called from Kimmeridge, in the Isle of Purbeck, where it is well exhibited.

Lamelliferous.—Consisting of very thin plates.

Laminæ.—The thin layers of which a stratum is composed.

Lava.—The melted matter which flows from volcanic craters and vents.

Lias.—A provincial term for a blue imperfect limestone containing numerous fossils of shells, and enormous saurian, or lizard-shaped reptiles, as at Lyme Regis.

Lignite.—Wood partly converted into coal, as that at Newton Bushel, Devon.

Lime.—An alkaline earth, the caustic principle of limestone, or carbonate of lime, when burnt.

Loam.—A mixture of earths which afford the best soils, generally including sand, clay, and lime.

Magnesia.—An alkaline earth, generally united as a carbonate with limestone, and forming by the union magnesian limestone.

Marl.—A mixture of clay and carbonate of lime, and often containing other fertilizing salts.

Matrix.—The natural position of a mineral in its parent rock or stratum.

Metamorphic Rocks.—Those rocks which appear to have undergone a change in their external form, and mineral arrangement, by the action of heat. Gneiss and mica are supposed to be altered slates, and crystalline, or primitive marble, altered limestone.

Mica.—One of the constituent minerals of granite, in which it appears in small shining plates, the laminæ of which are easily separated with the point of a knife. It is sometimes found in large and separate masses, the plates of which are used as a substitute for glass in windows.

Mica Slate.—A crystalline stratified rock, of similar mineral character to granite, with a large proportion of mica.

Molecules.—Very minute particles, whether elementary or compound.

Mountain Limestone.—A limestone rock, whose geological position is beneath the coal measures, on which account it is often called carboniferous limestone. It constitutes the lowest member of what is called the Carboniferous system.

Muriate of Soda.—The common name for culinary salt, but which, as we have explained before, is in fact a chloride of sodium.

Neutral Salts.—See Salts.

New Red Sandstone.—A stratum, or rather series of strata, consisting of sandstone, clays, and sometimes limestone, with beds of rolled stones. The characteristic colour is red, but the sandstones are often of a greenish grey, and sometimes approaching to white.

Nitrates.—Salts formed by the union of nitric acid with a base.

Nitre.—Nitrate of potash. See Nitric Acid.

Nitrogen.—One of the elements of most animal, and many vegetable substances, but chiefly abounding in the former. With oxygen it forms nitrous oxide, and nitric acid; and with hydrogen, ammonia.

Nodule.—A rounded and irregular mass of some mineral substance.

Old Red Sandstone.—A secondary rock, the next in order beneath the mountain limestone, and sometimes ranked with the Carboniferous system, but now considered as a member of the Devonian: it consists of dark red sandstones, clays, and limestones.

Oolite, or Roe-stone.—An imperfect limestone, of which there are several strata, and so called because it is composed principally of small round particles, resembling the roe of fish.

Organic.—Those substances and elements are called organic, which compose the tubes, vessels, and general mass of the bodies of animals and vegetables, and consist of carbon, hydrogen, oxygen, and nitrogen. When plants, or animal matters are burnt, these escape in the form of gases, while the inorganic, or mineral matter, remains in the form of ashes.

Organic Remains.—The remains of organized bodies (plants and animals) found in a fossil state.

Outliers.—Those detached portions of strata which are separated from the main body to which they belong, by what is called denudation, and resembling those heaps, or portions of a bed of earth left by excavators to indicate what has been removed.

Oxalates.—Salts formed by the union of oxalic acid with bases. See Acid, Oxalic.

Oxides.—Compounds produced by the union of oxygen with combustible substances, and with metals. Rust of iron and red lead are familiar instances of the latter. The alkalies and earths are oxides of metals, or metal-like elements. In many cases metals unite with two or more proportions of oxygen; such compounds are distinguished from the simple oxide by the term *per*-oxide, as *per*-oxide of iron, *per*-oxide of manganese.

Oxygen.—The most abundant and important element in nature. In its gaseous state, as a constituent of the atmosphere, it is

the active agent of the support of animal life, and of combustion, as well as in the decomposition of vegetable and animal substances.

Peroxides.—Oxides which contain the greatest quantity of oxygen they are capable of uniting with.

Phosphates.—Salts formed by the union of phosphoric acid with bases.

Plastic Clay.—The lowest member of the tertiary strata, resting upon the chalks, and composed of numerous beds of clay, sand, and flinty pebbles.

Plutonic Rocks.—Granite, and those other unstratified rocks which appear to have been formed from a molten state, and to have cooled and consolidated at great depths from the surface, and consequently under enormous pressure.

Porphyry.—An igneous, or unstratified rock, one of the class called trap rocks, and generally composed of crystals of felspar imbedded in a mass of the same, or some other mineral.

Portland Stone.—An imperfect limestone, the uppermost of the oolite strata of England; London is supplied with this valuable building stone from the island of Portland.

Potash, or Potassa.—The oxide of the brilliant metal potassium. This metal is extremely light, and has so powerful an affinity for oxygen, that when thrown into water, it unites with the oxygen of the water with such energy, as to cause instant combustion and flame.

Pudding Stone.—See Conglomerate.

Purbeck Limestone.—A stone belonging to the Wealden system.

Putrefaction.—The spontaneous decomposition of dead animal and vegetable substances, by which their elements are resolved into new and more simple compounds, most of them assuming a gaseous form, and some of which are very offensive.

Pyrites (Iron).—A yellow, shining, metallic substance, resembling brass, often seen on the surface of lumps of coal, and found in most of the strata forming radiating crystals. It is generally united with copper pyrites in the ores of that metal.

Quartz.—The German name, now in general use, for a mineral composed of pure silex, of which rock-crystal is a perfect specimen. Flints, agates, calcedony, and cornelian, are composed almost entirely of quartz.

Red Marl.—A name often given to the new red sandstone from the deep bed of red clay or marl, which forms a part of that stratum.

Rock Salt.—Those solid masses of common salt found in the new red sandstone in Cheshire, and in that and other strata of different countries.

Saltpetre.—A salt of nitric acid and potash (nitrate of potash).

Salts.—Crystalline substances formed by the union of acids with oxides of metals, or with alkaline or earthy bases. Those salts which still retain an acid taste, are called acid salts, to distinguish them from neutral salts, in which the taste of neither the acid nor of the base is perceptible. When an acid unites with two bases it is called a double salt, of which we have a familiar instance in alum, which is a sulphate of alumina and potash. Those salts whose crystals contain water are called *hydrous* salts, of which we have specimens in crystallized carbonate of soda, and sulphate of lime. Those salts, on the other hand, which contain no water, are called *anhydrous;* nitrate of potash (nitre,) and carbonate of lime are of the latter kind. There is a family of salts called chlorides, produced by the union of chlorine with metals and other substances, which is here noticed because it includes common salt, which is chloride of sodium.

The above very brief definition of salts would not suffice to explain the nature of many substances so called, but which, as having no connexion with agriculture, it would be incompatible with the object of this treatise to describe.

Sandstone.—A stone which is formed of agglutinated particles of either siliceous or calcareous sand, though the term is more commonly applied to siliceous stone.

Schist.—A term applied to slate rock.

Secondary Rocks.—An extensive series of rocks intermediate between the tertiary and the primary, and containing immense quantities of organic remains.

Sedimentary Rocks.—Those strata which have been formed by the materials conveyed by, or deposited from water. All the stratified rocks are called sedimentary.

Selenite.—Crystallized sulphate of lime or gypsum.

Septaria.—Nodules of stone, found abundantly in the London clay, called cement stone, as when calcined they produce the valuable cement so extensively used to cover and ornament buildings; they chiefly consist of clay, oxide of iron, and carbonate of lime, united with a certain portion of water.

Serpentine.—A trap, or unstratified rock, containing a considerable quantity of magnesia, which imparts to it an unctuous or soapy feel, from which some specimens of it are called soap-rock. It derives its name from the variety of colours it sometimes exhibits, in which green and red are the most characteristic. The Lizard, or the well-known Start Point, on the south coast of Cornwall, is composed of serpentine.

Shale.—Hard laminated clay has received this name from the German word *schalen,* to split.

Shingle.—A term given to pebbles, or water-worn stones, on the sea-shore.

Silex.—The earth of flints, the Latin name for that substance; the chief component of most sands.

Silica.—A pure earth, of which rock crystal is a perfect specimen. It is the most abundant earth in nature, as all the older rocks, which form the vast mountain masses of the globe, and also numerous minerals, are chiefly composed of it. It has been ranked by chemists amongst the acids because it combines in the manner of an acid, with alkalies and other oxides of metals.

Silicates.—Substances formed by the combination of silica with alkaline and earthy bases, the chemical names of which are derived from the combining substances; thus we have silicate of soda or potash, (glass,) silicate of alumina, lime, magnesia, iron, &c.

Siliceous.—Rocks or sands principally composed of silica are called siliceous.

Silt.—The finely divided matter carried down and deposited by rivers, and forming what are called alluvial soils on their banks, and deltas at their mouths.

Sodium.—The metallic base of soda. See Soda, and Common Salt.

Solution.—When a salt, or rather substance, is dissolved in water or an acid, it is called a solution of that substance.

Stalactite.—The tube-like and pendant masses of carbonate of lime seen projecting from the roofs of limestone caverns, and often of arches, and produced or deposited by water holding carbonate of lime in solution.

Stalagmite.—The same substance as stalactite, or a deposit of carbonate of lime, covering the sides and bottoms of the same caverns.

Stratified.—Formed in thick beds or layers called strata.

Stratum, (plural, *Strata*).—A thick mass of sedimentary or deposited matter, either loose, or hardened into rock. A deep and continuous mass of layers is generally called a stratum, and a thin or partial one, a bed.

Starch, or Farina.—The vegetable substance which constitutes the principal part of wheat, barley, rice, potatos, and many other seeds and roots, which by fermentation produces alcohol or pure spirit, the intoxicating principle of wine and beer.

Sulphur.—The well-known inflammable mineral substance used in making gunpowder; united with oxygen in different proportions, it forms sulphurous and sulphuric acids. It combines with metals and other substances to form those compounds called sulphurets; it unites with hydrogen in a gaseous form to produce the poisonous and offensive gas called sulphuretted hydrogen.

Sulphates.—Salts formed by the union of sulphuric acid with earths, and other metallic oxides, of which green copperas, (sulphate of oxide of iron,) and glauber salt, (sulphate of soda,) are instances.

Tannates.—Salts formed by the union of tannic acid with bases.

Tartrates.—Salts of tartaric acid. The tartar of wine casks is a tartrate, or rather *bitartrate* of potash, signifying that the potash is combined with two equivalents of the acid; this substan e is commonly called cream of tartar. The prefix *bi*, is used to express the same circumstance in many other salts.

Tertiary Strata.—Those strata which are newer, or lie above the chalk. They are distinguished from the secondary strata not so much by their mineral character, as by the great change they exhibit in their fossil remains of shell-fish and land animals, which in the most recent of them are either identical with, or approach very nearly to those which now inhabit the sea and land.

Tests, Chemical.—Substances, or liquids, used by chemists to ascertain the presence of other substances in a compound. Thus gallic acid, or the infusion of nut galls, is a test of the presence of iron; for if water contains a salt of iron in solution, a few drops of the infusion will cause a black precipitate, by the gallic acid forming an insoluble compound with the oxide of iron.

Trap Rocks.—These are unstratified and igneous rocks, which evidently in a molten or fused state have penetrated, fractured, and up-heaved the regular strata of all ages, and at great depths have been the proximate cause of all the great inequalities upon the face of the globe.

Travertin.—The stony deposit of springs holding carbonate of lime in solution. It is produced very rapidly, and in vast quantity, in certain lakes of the south of Italy, where it has been used as a building stone from the remotest times.

Urates.—Salts formed by the union of uric acid with bases.

Urea.—One of the components of urine, which when the urine putrefies, is converted into uric acid.

Woody Fibre.—Called in chemical language *lignin*—the mass of fibrous matter of wood, when all extractive, gummy, and resinous substances have been removed, first by treatment with alcohol, and afterwards by water.

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